Final Project Modification Report/Environmental Assessment

Main Report and Environmental Assessment

Sagamore Marsh Restoration Study
Bourne and Sandwich, Massachusetts

November 1996

US Army Corps
of Engineers
New England Division

EOEA File # 10174

EXECUTIVE SUMMARY

This report documents the feasibility investigation examining restoration of saltmarsh and estuarine habitat at Sagamore Marsh, located in Bourne and Sandwich, Massachusetts. Authorization for this study is provided under Section 1135 of the Water Resources Development Act of 1986 (PL 99-662), as amended. The study was conducted at the request of the Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA), the non-Federal sponsor.

Sagamore Marsh lies on the north side of the Cape Cod Canal at the Canal's east end. Tidal flushing of the marsh was restricted in the mid-1930's when the Canal was widened and deepened, and the marsh has become a predominantly fresh and brackish water system. The purpose of the investigation was to identify the feasibility of restoration of up to approximately 185 acres of former saltmarsh within identified constraints. The constraints were that restoration could not cause flooding of adjacent houses, could not affect the performance of adjacent septic systems, could not impact the salinity of nearby water supply wells, and could not impact navigation in the Canal.

Various alternatives which satisfied the study constraints were examined to determine the recommended plan. The recommended plan consists of: 1) replacing the existing degraded 48-inch diameter reinforced concrete culverts beneath two roads with 6-foot high by 12-foot wide reinforced concrete box culverts under each road; 2) installing electric sluice gates for primary flow control and stop logs for backup flow control; 3) deepening the man-made channel, which extends 1,100 feet into the marsh from the Canal, to remove siltation and maintain a constant channel slope; and 4) widening the man-made channel from an existing bottom width of 4-feet to a bottom width of 12-feet.

Hydraulic and groundwater analyses determined that the recommended plan will not cause the flooding of adjacent houses, will not affect the performance of adjacent septic systems, will not impact the salinity of nearby water supply wells, and will not impact navigation in the Cape Cod Canal. Project benefits are expected to be the restoration of approximately 50 acres of saltmarsh and estuarine habitat.

The Executive Summary Table displays the financial data concerning the recommended plan. The cost of the Section 1135 Project, including the feasibility study, design, construction, construction management, and baseline and post-construction monitoring is estimated at $1,522,000 of which the Federal cost share would be $1,141,500 and the non-Federal cost share would be $380,500. Annual operation and maintenance cost is estimated at $5,000. The Commonwealth of Massachusetts as the non-Federal sponsor will be responsible for all operation, maintenance, repair, replacement and rehabilitation (OMR&RR) of the project, as agreed to in the Project Cooperation Agreement. The non-Federal sponsor is responsible for the cost of all lands, easements, rights-of-way, relocations and disposal areas (LERRD). There is not expected to be any cost associated with temporary construction easements, since the land is owned by local, State, and Federal Governments. It is assumed at this time that there will not be any permanent easements required. This will be verified during the development of plans and specifications. All dredged and excavated material is proposed to be disposed of at the Town of Bourne municipal landfill, or at a suitable off-site location.

The report recommends that the selected plan be approved for development of plans and specifications and implementation under the Section 1135 authority.

EXECUTIVE SUMMARY TABLE

GENERAL RESTORATION FEATURES	
Feasibility Study	$ 345,000
Engineering and Design	$ 227,000
Construction Costs Including Contingencies	$ 776,000
Construction Management	$ 89,000
Operation & Maintenance Manual	$ 10,000
Post-Construction Monitoring	$ 75,000
TOTAL PROJECT COST	$ 1,522,000
ANNUAL COST	
Operations and Maintenance	$ 5,000
COST APPORTIONMENT	
Federal (75%)	
Feasibility Study	$ 258,750
Engineering and Design	$ 170,250
Construction Cost Including Contingencies	$ 582,000
Construction Management	$ 66,750
Operation and Maintenance Manual	$ 7,500
Post-Construction Monitoring	$ 56,250
Total - Federal	$ 1,141,500
Non-Federal (25%)	
Feasibility Study	$ 86,250
Engineering and Design	$ 56,750
Construction Cost Including Contingencies	$ 194,000
Construction Management	$ 22,250
Operation and Maintenance Manual	$ 2,500
Post-Construction Monitoring	$ 18,750
Total - Non-Federal	$ 380,500

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SECTION 1

INTRODUCTION

1.1 STUDY AUTHORITY

Authority to perform this investigation was provided under Section 1135 of the Water Resources Development Act of 1986 (PL 99-662), as amended. Section 1135, entitled "Project Modifications For Improvement of Environment" states, in part,

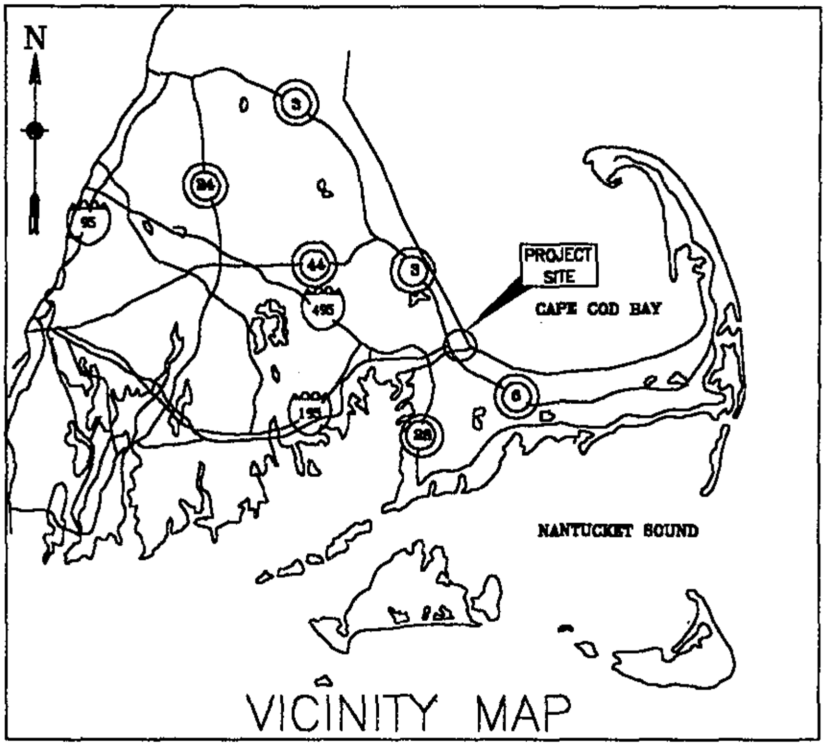
> "The Secretary [of the Army] is authorized to review the operation of water resources projects constructed by the Secretary before the date of enactment of this Act to determine the need for modification in the structures and operations of such projects for the purpose of improving the quality of the environment in the public interest."

1.2 STUDY PURPOSE

The purpose of the investigation was to identify and evaluate a range of alternatives to restore saltmarsh and estuarine habitat at Sagamore Marsh within identified planning constraints.

1.3 STUDY AREA

Sagamore Marsh is located in the towns of Bourne and Sandwich, Barnstable County, in eastern Massachusetts, as shown on Figure 1. Sagamore Marsh lies on the north side of the Cape Cod Canal, at the Canal's east end. The area of Sagamore Marsh studied for restoration consisted of the unfilled area which existed as saltmarsh and estuarine habitat prior to the reduction of tidal flows in the mid-1930's. The area is approximately 185 acres, and is shown on Figure 2. The area is bounded on the south by the Cape Cod Canal, Sagamore Hill, and the filled area to the north of Scusset Beach State Park; on the east by residential properties; on the north by Pilgrim Road and residential properties; and on the west by residential properties. The 140 acre filled area north of Scusset Beach State Park and east of Sagamore Hill was given only cursory investigation in this study, as it was known that removal of fill in that area would not be the most cost effective alternative for restoration of saltmarsh at Sagamore Marsh.



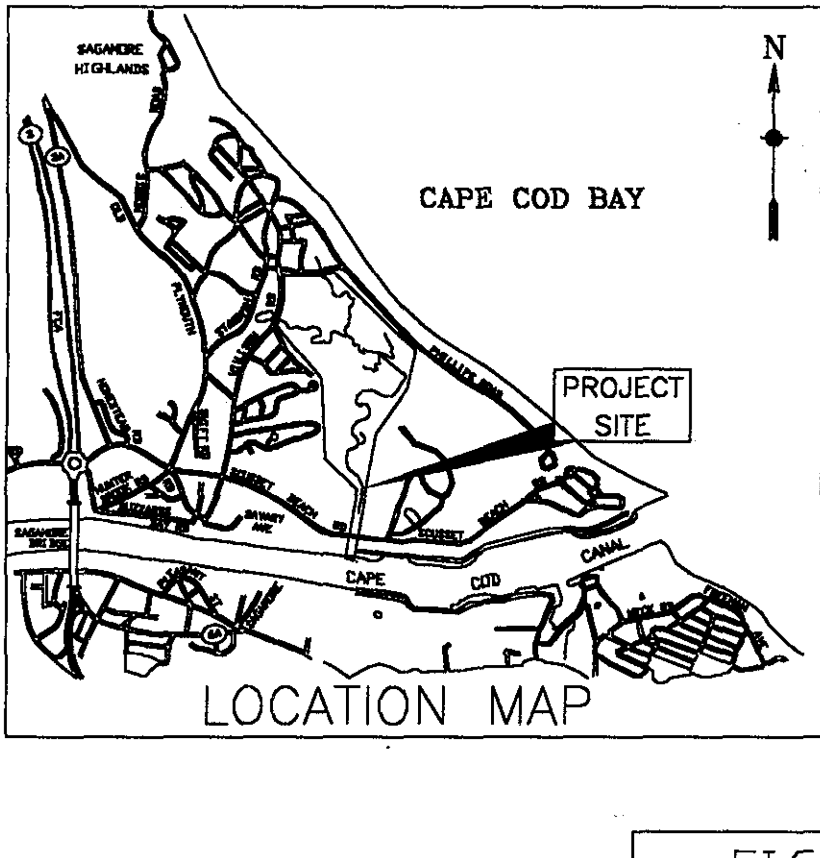


FIGURE 1

PROJECT LOCATION

SCALE: NOT TO SCALE

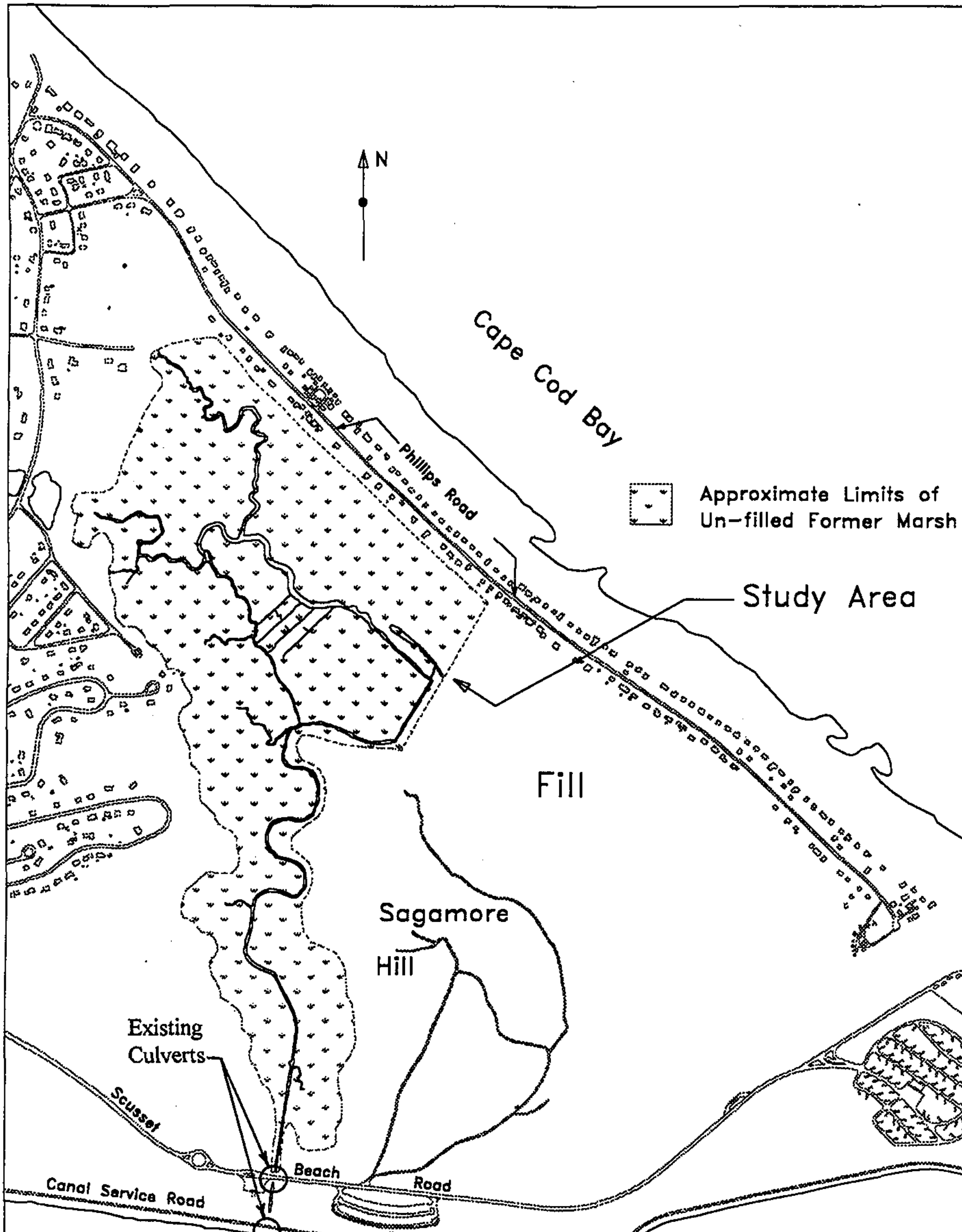


FIGURE 2

STUDY AREA

SCALE: 1" = 1000'

1.4 SITE HISTORY

The Federal Government purchased the Canal from the Boston, Cape Cod, and New York Canal Co. on January 21, 1927, as authorized by the Rivers and Harbors Act of 1927. The Corps of Engineers was assigned the responsibility of operating and maintaining the Canal in 1928. In September 1933 work was commenced under the Public Works Administration Program. This included widening the Canal to 250 feet and constructing two highway bridges and a vertical lift railroad bridge. The highway bridges were opened in July 1935 and the railroad bridge opened in December of that year. A mooring basin was constructed in April 1935 and dredging was performed in May 1935. A turning basin was constructed in 1945 and a boat basin was extended in 1958.

The east end of the Cape Cod Canal is protected from accretion of littoral material by two breakwaters which extend into Cape Cod Bay, one on the north side of the Canal and one on the south. The former Scusset River, which provided tidal flushing to Sagamore Marsh, flowed into Cape Cod Bay north of the present location of the north breakwater. Accretion of littoral material behind the north breakwater, along with the disposal of dredged material in the marsh area adjacent to the Canal in conjunction with expansion of the Canal in the mid-1930's, likely contributed to the reduction of tidal flows to the marsh. A 48-inch diameter culvert was constructed in the mid-1930's at the south end of the marsh to drain runoff from the marsh into the Canal. Scusset Beach State Park was later constructed, and a second 48-inch diameter culvert was constructed in-line with the first culvert beneath Scusset Beach Road. The location of the existing culverts is shown on Figure 2. The culverts have not been adequate to provide sufficient tidal flushing to maintain the former area of saltmarsh. The present level of tidal flushing is only sufficient to support approximately 11.7 acres of saltmarsh and estuarine habitat, primarily in the vicinity of the culvert.

1.5 STUDY SCOPE

The scope of the Section 1135 study consisted of identifying a range of alternatives which would restore saltmarsh and estuarine habitat to Sagamore Marsh within identified planning constraints. The study examined various alternatives to restore saltmarsh and estuarine habitat by increasing the amount of tidal inflow to areas of former saltmarsh. An incremental analysis of project costs and benefits was performed to identify the recommended alternative. The study included an Environmental Assessment of the considered alternatives.

SECTION 2

COORDINATION

2.1 COASTAL AMERICA

Saltmarsh restoration has been identified as a high priority of the national and regional Coastal America partnerships. This study was coordinated with Federal, state and non-governmental Coastal America partners, including the US Army Corps of Engineers; US Fish and Wildlife Service; US Geological Survey; US Environmental Protection Agency, Region I; and the National Marine Fisheries Service. The results of this study will be coordinated among the partners in the Northeast Regional Implementation Team of the Coastal America partnership to determine which agencies have programs that may assist the sponsor in follow-up activities in support of the Section 1135 project. Similar efforts in restoration of tidally constricted saltmarshes are underway in Connecticut and Rhode Island.

The Coastal America Partners and the Massachusetts Executive Offices of Transportation & Construction and Environmental Affairs signed a "Resolution to Restore Massachusetts Wetlands" in a ceremony on Sagamore Hill on June 1, 1994. This project represents the first major effort to implement the Resolution.

Saltmarsh restoration and control of common reed (*Phragmites australis*) on Cape Cod was also identified as a priority focus area under the Atlantic Coast Venture of the North American Waterfowl Management Plan. The North American Waterfowl Management Plan is an international agreement among Canada, Mexico and the United States established to protect, enhance, and restore waterfowl habitat in North America. As part of this plan, a series of joint ventures were established to coordinate resources to address specific areas and waterfowl populations. Sagamore Marsh lies within the area covered by the Atlantic Coast Joint Venture Plan.

2.2 PUBLIC MEETINGS

On May 11, 1994 a Public Meeting was held at the Oak Ridge Elementary School in Sandwich. The purpose of the meeting was to inform the public, elected officials, and state and Federal agencies of the Sagamore Marsh Restoration Section 1135 study, and to hear their comments on the study.

A Public Meeting was held October 24, 1994 at the Hoxie Elementary School in Sandwich. The purpose of the meeting was to present the proposed study methodology, and to obtain feedback from the public.

On May 7, 1996, another Public Meeting was held at the Hoxie Elementary School. The purpose of the meeting was to present the findings of the study to the public, and to hear their views. The meeting was scheduled in the middle of the Federal and State Public Notice comment periods.

2.3 AGENCY

The non-Federal sponsor, the Executive Office of Environmental Affairs Wetlands Restoration and Banking Program, was the lead agency for the Commonwealth. This study was coordinated with the following agencies:

Federal
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geologic Survey
National Marine Fisheries Service

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
- Wetlands Restoration and Banking Program
- Coastal Zone Management Office
- MEPA Unit

Department of Environmental Management
- Division of Parks
- Division of Water Resources

Department of Environmental Protection
- Division of Water Supply
- Division of Water Pollution Control
- Division of Wetlands & Waterways

Department of Fisheries, Wildlife, and Environmental Law Enforcement
- Division of Fisheries and Wildlife
- Natural Heritage Program
- Division of Marine Fisheries

Massachusetts Historical Commission
- State Historic Preservation Officer

Town of Bourne
Board of Health
Board of Selectmen
Conservation Commission

Town of Sandwich
Board of Health
Board of Selectmen
Conservation Commission

Regional
Cape Cod Commission
Cape Cod Mosquito Control District
North Sagamore Water District

2.4 SUMMARY OF PUBLIC AND AGENCY COMMENT

The following is a synopsis of comments received as part of the Environmental Assessment, with a short explanation as to how that view was addressed within the context of the restoration study.

- The Massachusetts Division of Fisheries and Wildlife, through their Natural Heritage & Endangered Species Program, indicated that a State Species of Concern (four - toed salamanders) were present at the project area. After consideration, it was concluded that populations inhabit areas which appear to be above the levels of tidal influence that will occur as a result of this project. Consequently, there should be no adverse effect on this species. This will be confirmed at the beginning of the plans and specifications phase. The monitoring program which will be implemented as part of this project is designed to assess any changes over time to habitat type which could negatively affect the species.

- The National Marine Fisheries Service supports the restoration project. A site visit was conducted and it was concluded that the marsh is obviously "receiving an inadequate quantity of tidal flow" and that the restoration effort presented an opportunity for "retroactive mitigation" for some of the impacts associated with the construction of the Cape Cod Canal. The following recommendations were made for consideration during the planning and implementation of this project:

(a) Maintain the quality of the existing in-channel estuarine habitat as much as practicable: This was a project objective and has been accomplished through project design which will increase water quality and flow which should actually improve estuarine habitat.

(b) Implement a monitoring program which assesses the effectiveness of the restoration project: The EA provided predictions of the post-project plant communities for the preferred alternative. A monitoring plan has been developed which has identified stations to be sampled both as baseline and at selected intervals post construction to determine the effects of project implementation on the wetlands / saltmarsh, vegetated shallows (eelgrass) and on the state listed rare species four-toed salamander. The results of this monitoring program will serve to document the degree of success for this project.

(c) Evaluate the benefits and impacts associated with active eradication of the Phragmites australis: The primary purpose of the restoration study will be to restore tidal flushing to a greater portion of the saltmarsh of which a direct consequence will be a reduction in the abundance of Phragmites on the site and an increase in saltmarsh vegetation. Previous studies conducted in similar areas found that within three years following restoration efforts, significant reductions in Phragmites occurred with various saltmarsh species increasing in dominance. Given this relatively short time period of expected vegetational shifts in dominance, the costs and level of effort associated with the active eradication of Phragmites at the project area would outweigh the expected accrued benefits.

- The U.S. Fish and Wildlife Service supports this project. They feel that this effort adds to the total effort of the many acres of saltmarsh and associated habitats which have been restored in Massachusetts. They concluded that no federally-listed or proposed, threatened and endangered species under their jurisdiction occur in the project area.

- The Massachusetts Audubon Society supports the efforts to restore the Sagamore Marsh through the Massachusetts Wetlands Restoration and Banking Program. Since this project is of a relatively large scale as compared to other restoration projects, there is a greater risk of unanticipated impacts and as a result, requires more comprehensive planning and monitoring than a smaller project. The monitoring plan established for this project should serve to document both the enhancements to the salt marsh as well as any unexpected impacts over time.

- The Town of Sandwich Conservation Commission's comments were concerned primarily with establishing lines of communication between "the town(s) and the design and controlling agencies" to assess any unexpected negative impacts which may occur post construction (i.e. serious flooding / impact on septic systems). This concern will be addressed by the implementation of the proposed monitoring program which documents existing conditions and changes to selected parameters over time. This information should be conveyed to the appropriate town officials as data / reports become available. Another concern related to the effective management, and the necessity of mutually agreed upon protocols for sluice gate operation during unexpected environmental conditions (i.e oil spills).

- The Town of Sandwich Board of Health indicated that they agreed that the project would not affect septic systems in the area. It was requested that the monitoring program results be conveyed to their office since the results would be beneficial for future designs.

- The North Sagamore Water District requested that a bond be in place in the event that any unexpected impacts occur to their well as a result of the project.

- The Executive Office of Environmental Affairs Wetlands Restoration and Banking Program supplied numerous comments relative to the draft Project Modification Report / Environmental Assessment. Given the extensive nature of these comments, a general overview follows.

Numerous comments were made which dealt with the hydraulic modeling and management of the project after construction to "maximize restoration". Additional comments related to culvert sizes and their effect on the four-toed salamander, ("Both drainage and the potential for impacts to four-toed salamanders would be worse with alternatives larger than the recommended 6'H x 12'W alternative). There was also discussion relative to their involvement in conducting the various tasks of the monitoring program. Other comments related to sluice gate design to minimize flooding and geotechnical investigation results and its bearing on project design. Additional discussions included septic systems, flood analysis, operation and maintenance of sluice gates as well as comments on the environmental assessment.

Other major comments compiled by the Wetlands Restoration and Banking Program on behalf of the agencies of the Executive Office of Environmental Affairs were numerous, technical in nature and related to specifics regarding alternative selection. Extensive coordination among the Army Corps of Engineers and the various regulatory agencies ensured agreement on all major components and aspects affecting the design, implementation and monitoring of this restoration effort. Major environmental concerns were adequately addressed in the Environmental Assessment / Project Modification Report..

- The Cape Cod Mosquito Control Project submitted comments which discussed their efforts in planning for and maintaining the mosquito control ditches of Sagamore Marsh, after project completion. It was determined that no more than $20,000.00 would be needed for surveillance and maintenance efforts. In terms of monitoring, they plan on conducting surveillance throughout the restoration effort.

- The Cape Cod Commission is supportive of this project as well as other wetland restoration initiatives. Their comments related to the Draft Modification Report / Environmental Assessment. Discussions related to culvert size versus amount of marsh to be restored (maximize benefits), tide gate selection, their functioning and wetland / wildlife habitat resources. Major comments were addressed within the Environmental Assessment / Project Modification Report.

- Comments supplied by the Department of Environmental Protection were related to the draft report Hydrogeology and Analysis of the Ground - Water Flow System, Sagamore Marsh Area, Southeastern Massachusetts. Other comments related to a determination that the Sagamore Marsh Restoration Project is eligible for permitting under the issuing authority. Additionally, it was also relayed that "no such project may be permitted without a variance if it will have an adverse effect on rare wildlife habitat".

SECTION 3

PROBLEM IDENTIFICATION

3.1 EXISTING CONDITIONS

Since the reduction of tidal flow, Sagamore Marsh has changed from an area which consisted of predominantly saltmarsh and estuarine habitat to an area which is dominated by common reed (*Phragmites australis*, referred to in this report as *Phragmites*). Saltmarsh and estuarine habitat still exists at the south end of the marsh in the vicinity of the 48-inch culvert, as that area receives some degree of tidal flushing. The eastern and western perimeters of the marsh contain primarily forested/shrub swamp vegetation, the northern end of the marsh contains a freshwater pond and small areas dominated by cattails, and the filled area of the marsh is predominantly a shrub and emergent wetland. The Environmental Assessment contains more detailed information on existing vegetation.

Ecologically, *Phragmites* is a relatively low value species compared to saltmarsh plant species. The tendency of *Phragmites* to grow in dense stands which exclude other species of vegetation reduces the benefits which accrue to a marsh system with a diversity of vegetation. Although its productivity in terms of detrital export is quite high, the value of its plant material is limited. Whereas a portion of saltmarsh production is exported to the aquatic and terrestrial food webs, *Phragmites* production is to a large extent unavailable to food webs. It has relatively low value as a food item because of the coarseness of its stems and leaves and its hairy seeds. In addition, *Phragmites* cover is a potential fire hazard, and *Phragmites* marshes contain mosquito breeding areas which are difficult to control effectively.

3.2 FUTURE CONDITIONS WITHOUT THE SECTION 1135 PROGRAM

Outside of this Section 1135 study, there are no known plans to restore the former habitat of Sagamore Marsh. If no action is taken under the Section 1135 authority, it is expected that a large portion of Sagamore Marsh will continue to support *Phragmites* with limited ecological value. The benefits of increasing the area and productivity of estuarine habitat would not occur. In addition, the dense stand of *Phragmites* will remain a fire hazard, and will complicate efforts to control mosquitos.

3.3 BENEFITS OF RESTORATION

By increasing the area of saltmarsh and reducing the area of *Phragmites*, restoration of Sagamore Marsh will improve the value of the site for aquatic productivity, shellfish and fin fish production, and wildlife habitat; reduce the existing fire hazard; and improve conditions for mosquito control.

Saltmarshes are an important source of food for invertebrates such as worms, snails, clams, and crabs which feed on living and decaying saltmarsh vegetation. The invertebrates in turn become a source of food for animals higher in the food web such as fish, mammals, and birds. Smaller fish become food for larger fish, including commercial species. Mammals which use the marsh feed on populations lower in the food web. Saltmarshes also provide valuable habitat for nesting birds. The geographic extent of restoration benefits would be enhanced by its potential value as a feeding, nesting and resting area for migratory birds, including waterfowl. Restoration of the marsh would also provide benefits associated with aesthetics, public education, recreation, and scientific research.

Restoration of tidal flow will also improve conditions for mosquito control. Areas which are ponding water will be easier to find and treat. The areas can then either be managed by changing the topography, or by implementing Open Marsh Water Management to create permanent reservoirs for fish which eat mosquito larvae. The Environmental Assessment contains more detailed information on the expected benefits of restoration.

3.4 CONSTRAINTS TO RESTORATION

Although there are widely-acknowledged benefits to the restoration of saltmarsh and estuarine habitat, the benefits must be balanced against any potential impacts. The constraints which governed selection of restoration alternatives at Sagamore Marsh were that restoration could not cause flooding of adjacent houses, could not affect the performance of existing adjacent septic systems, could not affect the salinity of nearby water supply wells, and could not impact navigation in the Cape Cod Canal.

To ensure that restoration of Sagamore Marsh would not cause flooding of adjacent houses, a complete hydraulic and hydrologic analysis of the system was conducted. In order to assess the potential effect of restoration on the performance of existing septic systems, the Corps contracted with the US Geological Survey to install monitoring wells and to study groundwater flow in the area. In addition, the Corps coordinated with the Sandwich Board of Health to discuss septic system regulations and the scope of the groundwater study.

To assess the potential effect that restoration could have on water supply wells belonging to the North Sagamore Water District and the Commonwealth of Massachusetts' Department of Environmental Management, the Corps contracted with the US Geological Survey to install monitoring wells, perform a pump test to determine the zone of contribution of the North Sagamore Water District's "Beach Well", and to model groundwater flow in the area.

The velocity of flow which would leave the marsh and enter the Cape Cod Canal was determined from the hydraulic model to ensure that restoration would not affect navigation in the Canal.

SECTION 4

INITIAL SCREENING OF RESTORATION ALTERNATIVES

4.1 INTRODUCTION

Following identification of the benefits and constraints of marsh restoration, several restoration alternatives were developed and screened to identify feasible alternatives which warranted further investigation. The primary screening criteria were engineering feasibility, ecological benefits, cost, and acceptability to the sponsor.

4.2 RESTORE TIDAL FLUSHING THROUGH THE FORMER SCUSSET RIVER

This alternative consisted of re-establishing the former natural course of the Scusset River, which existed prior to construction of improvements to the Cape Cod Canal in the mid 1930's. The Scusset River had its mouth at Cape Cod Bay in the vicinity of the southern end of Phillips Road, and flowed westerly to and then north along Sagamore Hill, as shown on Figure 3. The Scusset River was the source of tidal flushing for the now degraded saltmarsh. This alternative was eliminated from further consideration because it would require construction of either a closed conduit, an open channel, or a conduit and channel system through the beach, dune and Phillips Road in order to introduce tidal waters into the marsh.

Construction of any of these conveyances would require the excavation of beach and dune resources, and possibly the purchase and removal of homes on Phillips Road. The required channel or conduit would be significantly longer than the existing culvert and channel. Construction of a channel or conduit and channel system would also require construction of jetties in order to minimize shoaling in the entrance, and periodic maintenance dredging would likely be required. All of these factors increased the cost and decreased the engineering feasibility of this alternative to a level which eliminated the alternative from further consideration.

4. 3 RESTORE THE FILLED AREA OF SAGAMORE MARSH TO SALTMARSH AND ESTUARINE HABITAT

This alternative consisted of restoring saltmarsh and estuarine habitat to the area north of Scusset Beach State Park and east of Sagamore Hill by removing fill and introducing tidal flushing. This alternative was removed from further consideration because of the associated high cost. It would require the excavation of 2-4 feet of dredged material from an area of approximately 140 acres (approximately 675,000 cy of excavation) in order to re-establish ground elevations which would support saltmarsh vegetation. That requirement eliminated the cost-competitiveness of this option compared to restoring tidal flow to former areas of saltmarsh which have not been filled.

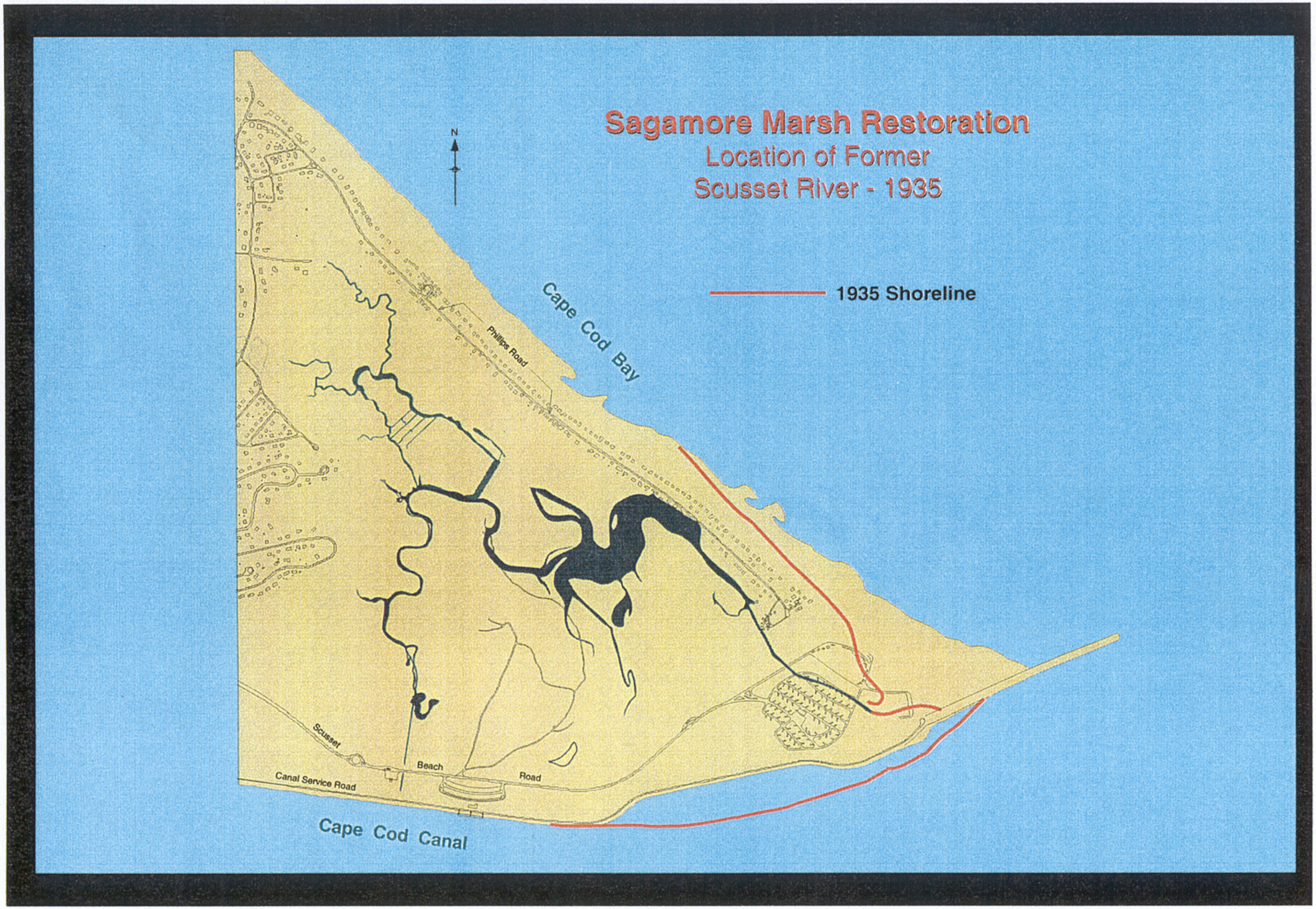

Sagamore Marsh Restoration
Location of Former
Scusset River - 1935
N
1935 Shoreline
Cape Cod Bay
Phillips Road
Scusset
Beach
Road
Canal Service Road
Cape Cod Canal

FIGURE 3

4.4 CONSTRUCT AN ADDITIONAL CONVEYANCE

This alternative consisted of constructing a new conveyance, to supplement the existing 48-inch culvert, in order to introduce tidal flushing into the degraded marsh, either from Cape Cod Bay or from the Canal. This would consist of a closed conduit, an open channel, or a conduit and channel system. This alternative was similar to the alternative discussed in paragraph 4.3, but allowed more flexibility as to where the conveyance would be located.

Any conveyance constructed from Cape Cod Bay would have the high cost associated with jetties and channel maintenance discussed in paragraph 4.3. Any supplemental conveyance constructed from the Cape Cod Canal would have to have a hydraulic capacity greater than or equal to the existing culvert and channel system. The existing small culverts, which pass beneath the Canal Service Road and Scusset Beach Road, and the ditches which drain into them have very low hydraulic capacity. Therefore, substantial excavation would be required to construct a supplemental conveyance. This factor made this alternative more costly to construct than increasing the hydraulic capacity of the existing culvert and channel system. This alternative was eliminated from further consideration due to cost and engineering feasibility.

4.5 INCREASE THE HYDRAULIC CAPACITY OF THE EXISTING CULVERT AND CHANNEL SYSTEM

This alternative consisted of replacing the existing 48 inch diameter culverts beneath the Canal Service Road and Scusset Beach Road with larger culverts, and possibly increasing the size of the existing channel between the roads and upstream of Scusset Beach Road. This alternative was selected for further consideration, since it offered the potential to increase the amount of tidal flushing to the marsh with the least cost. Within this general alternative, several more specific restoration alternatives were formulated and analyzed. The alternatives are described in Section 6. Section 5 outlines the methodology used to model existing and proposed conditions in order to formulate and analyze the various alternatives.

SECTION 5

OVERVIEW OF STUDY METHODOLOGY

5.1 INTRODUCTION

This section presents an overview of the methodology used to analyze various alternatives to restore saltmarsh at Sagamore Marsh.

5.2 MODELING OF EXISTING CONDITIONS

5.2.1 Topographic Survey

Existing mapping was available showing topography at 2- foot contour intervals within and adjacent to the marsh. A portion of the mapping, showing the 2-foot NGVD [1], 4-foot NGVD, and 6-foot NGVD contour intervals is shown on Figure 4. Two-foot contour mapping is fairly detailed mapping for such an extensive area. However, more detailed topographic information was required, since the surface elevation of the degraded marsh ranges primarily between 2-feet and 4-feet NGVD. Therefore cross-sections were surveyed at five locations within the marsh (transect 3 was surveyed to determine the elevation of fill in that location, but was not used in the modeling of existing or restored conditions). The location of the surveyed cross-sections, referred to as "transects" in this report, are shown on Figure 5, and the transects are shown on Figure 6. Appendix A - "Topographic Survey" contains more detailed information on the topographic survey.

5.2.2 Hydraulic Model and Analysis

Table 1 shows the estimated tide levels in the Cape Cod Canal at Sagamore. The tide levels were estimated from short-term National Ocean Service (NOS) measurements within the Cape Cod Canal at Sagamore, with correlation to the Boston, Massachusetts NOS Tide Gage Data and the Corps of Engineers Tidal Flood Profiles, New England Coastline, dated September 1988.

A numerical hydraulic model was prepared to model salt water flow from the Cape Cod Canal into Sagamore Marsh. The model used was UNET, a one-dimensional model for unsteady flow through a full network of open channels. This model became available for use in September 1992, and is the most advanced model readily available. Appendix B - "Hydrology and Hydraulics" contains the complete report of the hydraulic model and analysis, including the hydrologic analysis.

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[1] National Geodetic Vertical Datum of 1929, a reference datum.

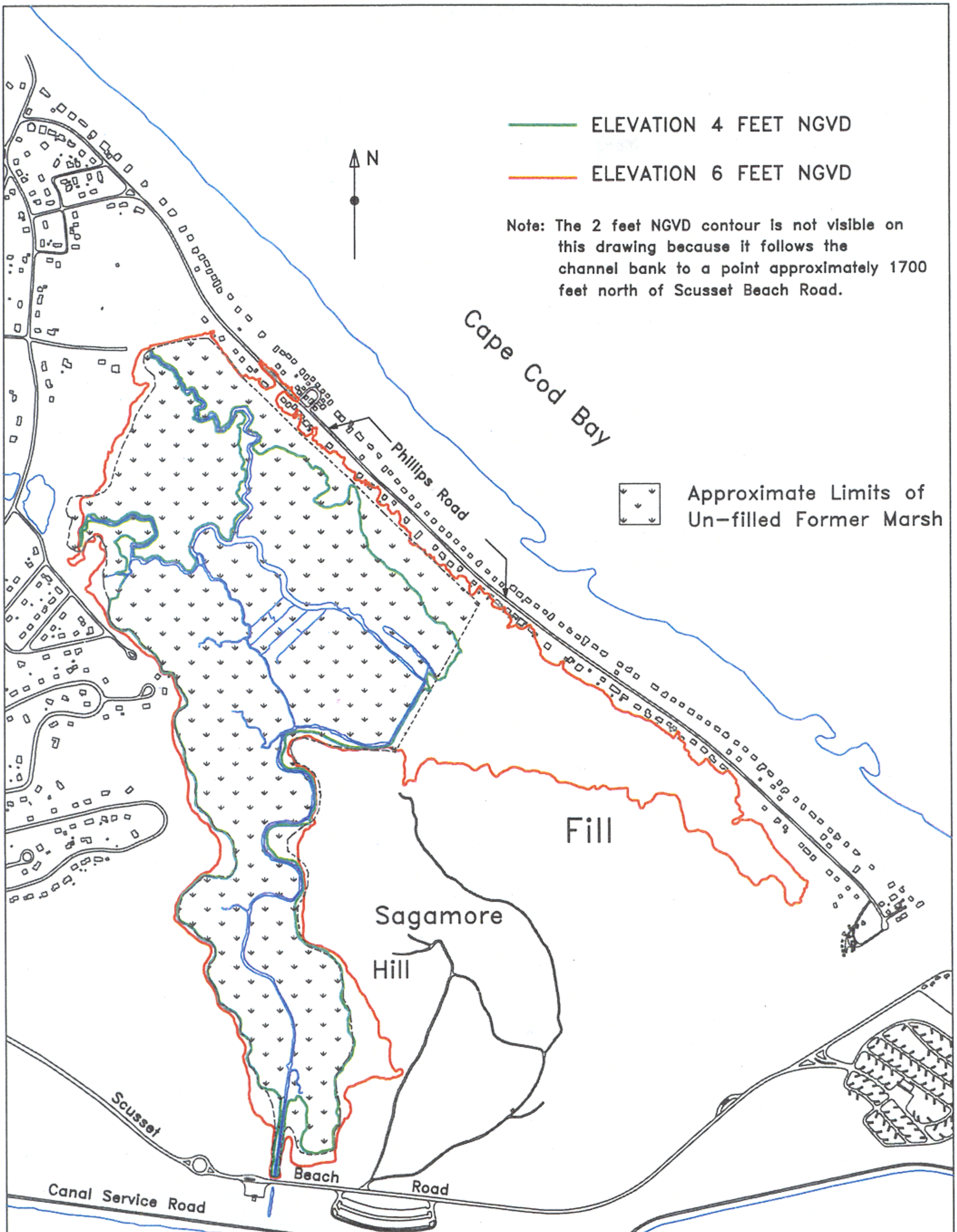
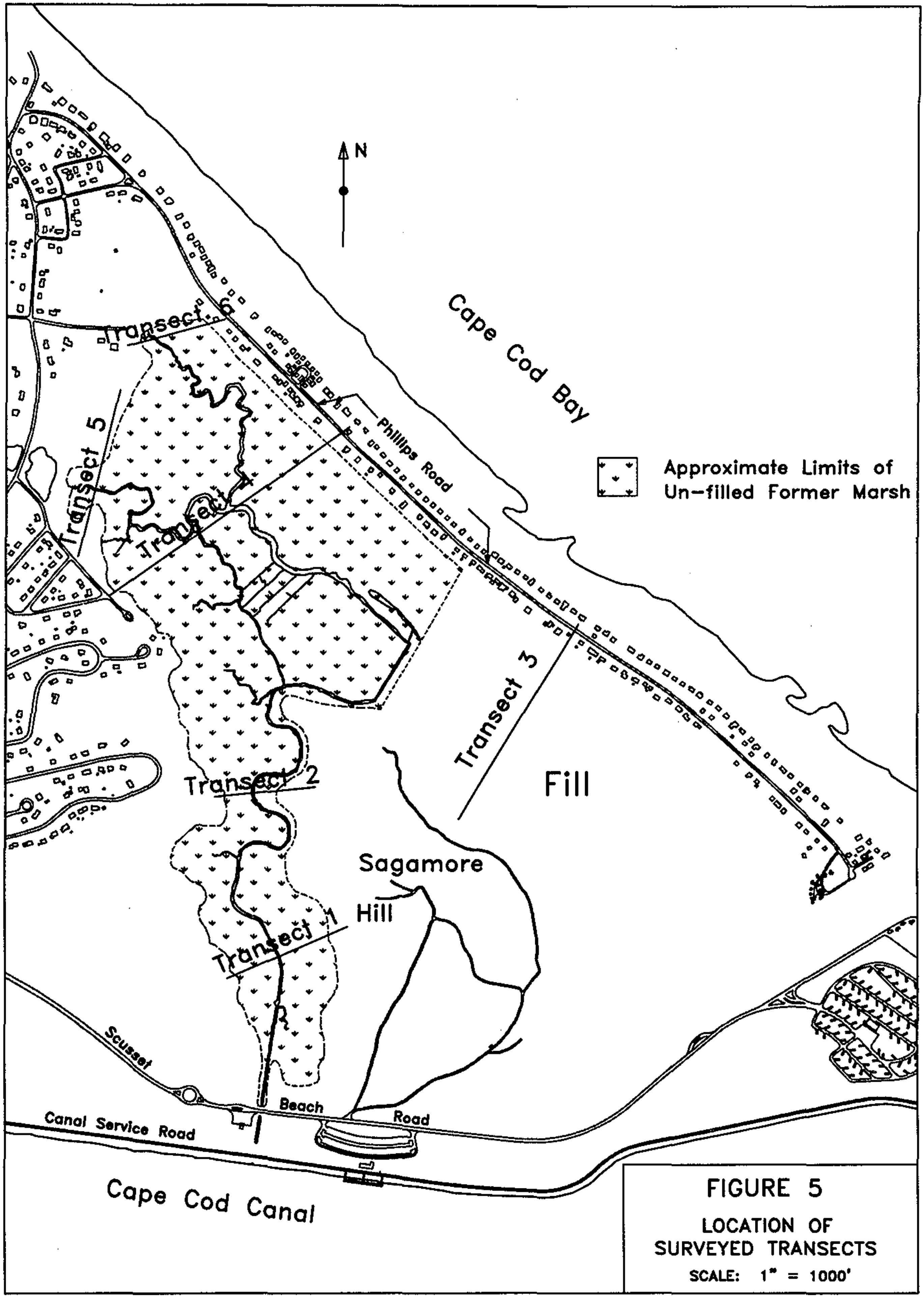
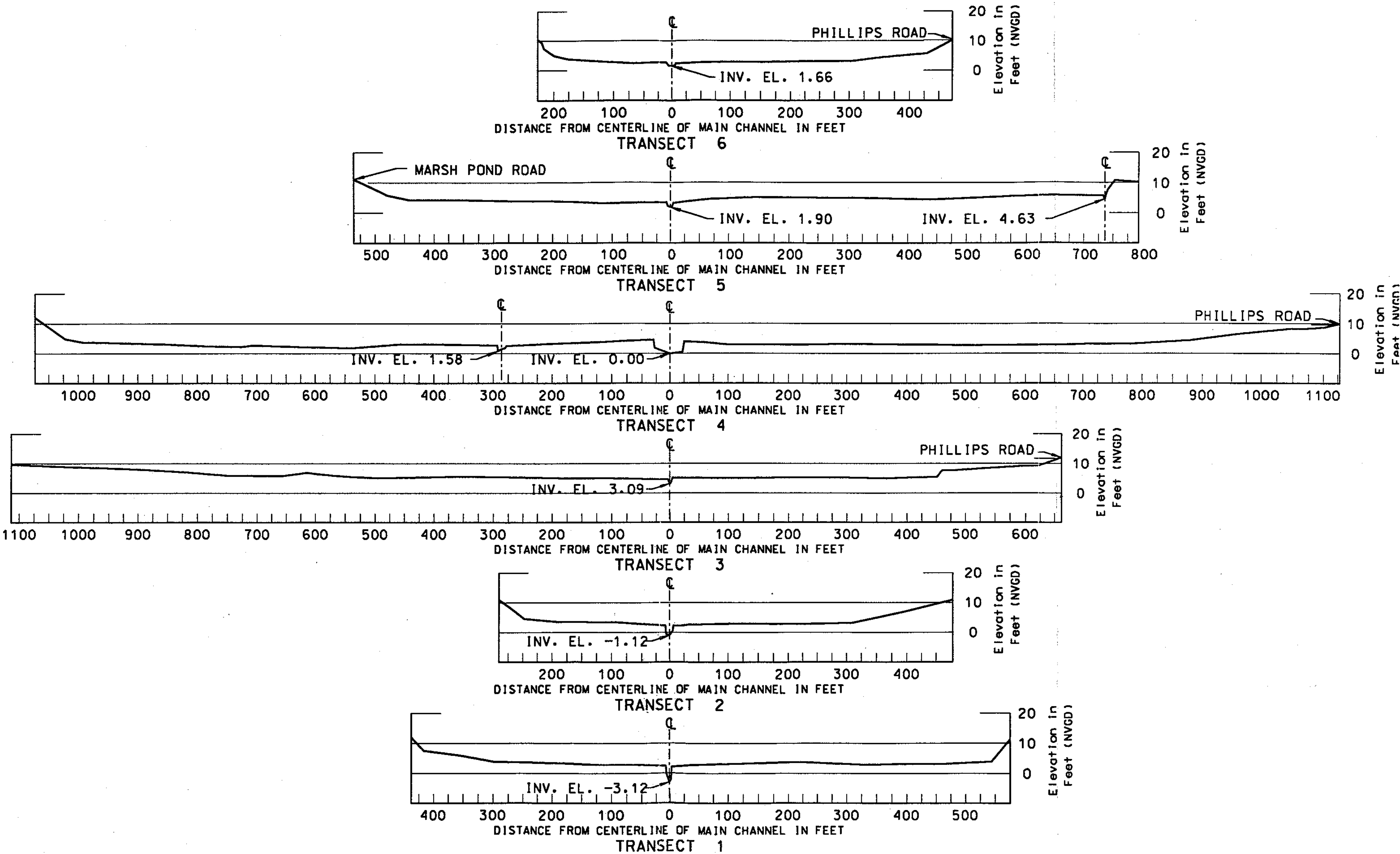


FIGURE 4
TOPOGRAPHY WITHIN SAGAMORE MARSH
SCALE: 1" = 1000'


N
Cape Cod Bay
Phillips Road
Approximate Limits of
Un-filled Former Marsh
Transect 6
Transect 5
Transect 4
Transect 3
Transect 2
Transect 1
Fill
Sagamore
Hill
Scusset
Beach
Road
Canal Service Road
Cape Cod Canal
FIGURE 5
LOCATION OF
SURVEYED TRANSECTS
SCALE: 1" = 1000'



TRANSECT CROSS SECTIONS

CROSS SECTIONS ARE STATIONED SOUTH TO NORTH LOOKING NORTH
SCALE: HORIZONTAL 1" = 150'
VERTICAL 1" = 30'

FIGURE 6
TRANSECTS

Table 1

ESTIMATED TIDE LEVELS
CAPE COD CANAL AT SAGAMORE

Frequency of Tide Level	Tide Level (Feet NGVD)
100-Year Storm High Water	10.4
50-Year Storm High Water	9.9
10-Year Storm High Water	8.3
1-Year Storm High Water	6.9
Maximum Predicted Astronomic High Water	6.5
Two Times Per Month High Water	5.6
Eight Times Per Month High Water	4.9
Mean High Water Spring (MHWS)	4.6
Mean High Water (MHW)	4.1
Mean Tide Level (MTL)	0.1
National Geodetic Vertical Datum (NGVD)	0.0
Mean Low Water (MLW)	- 3.8
Mean Lower Low Water (MLLW)	- 4.1
Mean Low Water Spring (MLWS)	- 4.4
Minimum Predicted Astronomic Low Water	- 5.9

Input to the model consisted of: tide elevations in the Canal and in the marsh; elevation survey data within the marsh including channel bottom elevations, channel bank elevations, channel widths, and marsh surface elevations; channel and marsh surface "roughness", primarily indicated by the channel composition and the type and height of vegetation on the marsh; and fresh water inflows to the marsh from rainfall and runoff.

Four "staff gages" were installed at the time the topographic survey was performed, and the elevation of each staff gage was surveyed in order to provide a means to read water levels (the staff gages consisted of boards painted and marked in increments of feet and tenths-of-a-foot). One staff gage was installed in the Cape Cod Canal mounted to the fish pier east of the Canal Service Road culvert. The other three staff gages were installed in the marsh channel: one midway between the Canal Service Road and Scusset Beach Road, one 1,300 feet from the Canal, and one 3,600 feet from the Canal.

A wooden reference stake was installed in the marsh channel approximately 400 feet east of the pond on the east side of Williston Road, and used to measure water surface fluctuations. The bottom elevation of the 24" diameter culvert beneath the dirt-road extension of Pilgrim Road at the northern end of the marsh was surveyed, and provided a reference elevation to measure water levels at that location. The locations of the staff gages, stake and culvert are shown on Figure 7.

Water levels were read at each staff gage, stake, and culvert location described above over one full tidal cycle, and the hydraulic model was "calibrated" to match those levels to the greatest degree possible for existing conditions. The readings were taken on December 5, 1994, since the predicted high tide level in the Canal was among the highest astronomic[2] tides for the year. It was desirable to "calibrate" the model for high astronomic tide levels, as one of the design conditions for the study was to ensure that restoration does not increase the flooding potential of homes bordering the marsh.

The hydraulic model was then used to estimate water surface elevations at each of the surveyed cross-sections within the marsh for tide levels of various frequencies in the Cape Cod Canal under existing conditions. The water surface elevations predicted by the hydraulic model were then used to estimate the area of overbank presently inundated by salt water at each cross-section for each frequency of tide level under existing conditions.

5.2.3 Environmental Analysis

An environmental analysis was performed as part of the incremental analysis to quantify the benefits of the restoration alternatives. Appendix C contains the complete report of the incremental analysis.

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[2] Caused by the relative positions of the earth, moon, and sun, as opposed to storms.

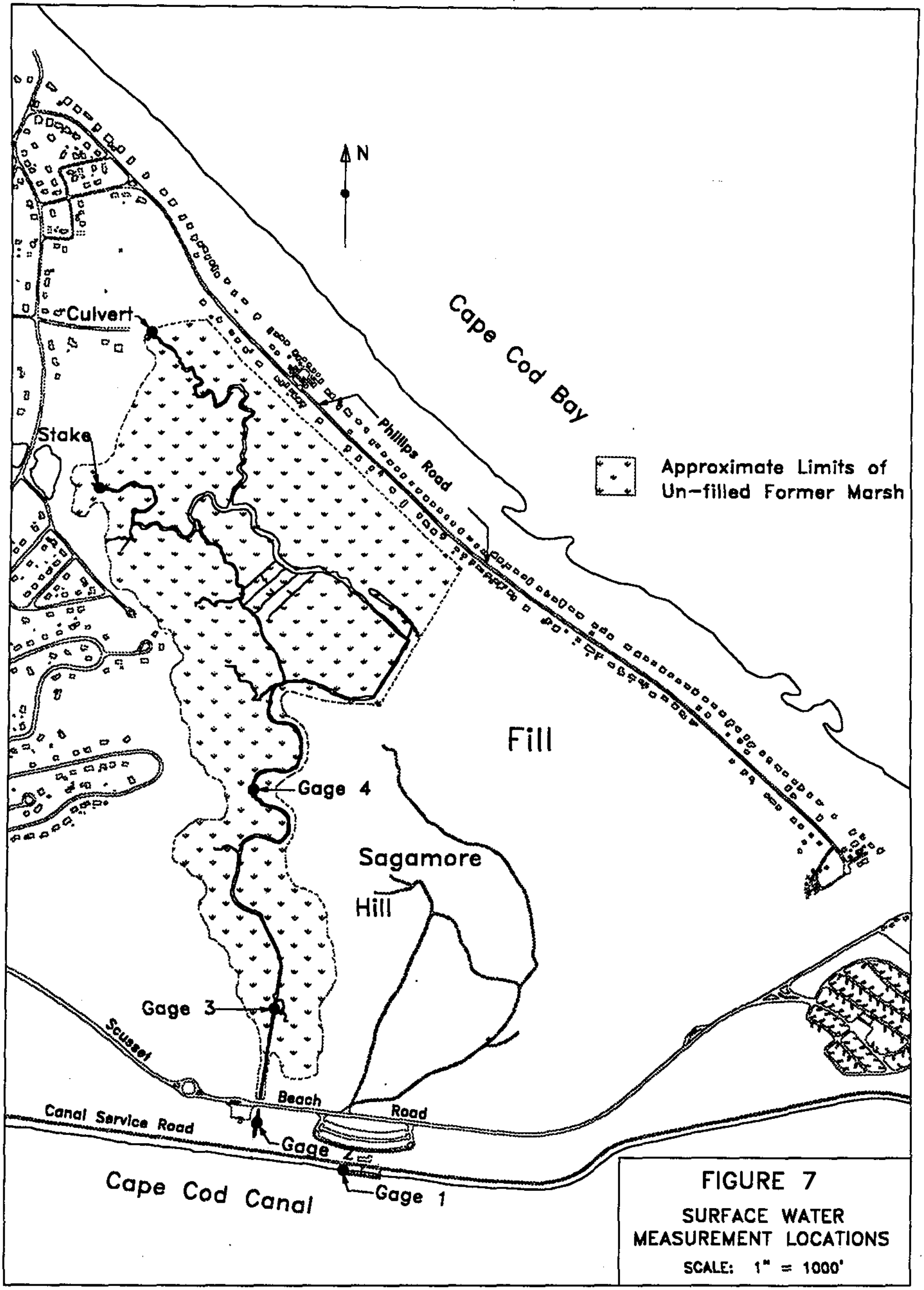

FIGURE 7
SURFACE WATER MEASUREMENT LOCATIONS
SCALE: 1" = 1000'

As stated in Section 5.2.2, the water surface elevations predicted by the hydraulic model were used to estimate the area of overbank presently inundated by salt water at each cross-section for each frequency of tide level under existing conditions. In the environmental model and analysis, each of the surveyed cross-sections was assumed to be representative of an area of the marsh in the vicinity of the cross-section. The limits of each area were established based on the nature of the vegetation as observed on aerial photography and verified by field inspection. The area inundated at various frequencies was compared to the existing area of saltmarsh, intertidal habitat, and stunted *Phragmites*. The analysis concluded that, under existing conditions at Sagamore Marsh, saltmarsh, intertidal habitat, and stunted *Phragmites* appear in areas which are inundated by salt water eight times per month. The high-tide elevation in the Cape Cod Canal corresponding to this frequency is elevation 4.95 feet NGVD, which is slightly higher than mean spring high water.

5.3 MODELING OF RESTORED CONDITIONS

5.3.1 Hydraulic Model

Once the modeling of existing conditions was completed, the hydraulic model was used to predict water surface elevations which would occur eight times per month at each of the surveyed cross-sections for each of the larger culvert sizes that were analyzed.

The water surface elevations from the hydraulic model were then used in the environmental model and analysis to estimate the area inundated by salt water eight times per month for each culvert size.

5.3.2 Environmental Analysis

As stated in Section 5.2.3, under existing conditions at Sagamore Marsh, saltmarsh and intertidal habitat appear in areas which are inundated by salt water eight times per month. The replacement of the existing 48-inch diameter culverts with larger culverts will increase the amount of salt water entering the marsh. This is expected to increase soil water salinity in the root zone of marsh vegetation to around 20 parts per thousand or greater, which *Phragmites* vegetation cannot tolerate. Therefore, if larger culverts are installed, it is expected that the area inundated by salt water eight times per month will become saltmarsh and intertidal habitat.

The estimated net area of saltmarsh and estuarine habitat expected to be restored by each culvert alternative was calculated by subtracting the area of existing saltmarsh and estuarine habitat from the total area predicted to be inundated by salt water eight times per month for each culvert size.

SECTION 6

FORMULATION OF FEASIBLE RESTORATION ALTERNATIVES

6.1 INTRODUCTION

Once it was established that the most feasible way to restore saltmarsh and estuarine habitat at Sagamore Marsh was to increase the size of the existing 48-inch diameter culverts beneath the Canal Service Road and Scusset Beach Road, the hydraulic model was used to develop various combinations of culvert sizes, channel sizes, and culvert and channel invert[3] elevations which would increase high tide elevations within Sagamore Marsh.

6.2 SENSITIVITY ANALYSIS

A sensitivity analysis was conducted using the hydraulic model in order to determine the range of culvert alternatives to be considered, and the optimum invert elevations of the culverts and tidal channel.

It was determined that the minimum cost-effective culvert opening was 6-feet high by 6-feet wide. The sensitivity analysis determined that a minimum culvert height of 6 feet would be required to use as much of the 7.9 foot mean tide range and 9.0 foot mean spring tide range as possible. The study team determined that installation of culverts less than 6-feet wide would restrict high tide levels within the marsh significantly, and there would be minimal associated cost savings.

The largest culvert opening analyzed in detail was 10-feet high by 40-feet wide. The hydraulic model showed that an uncontrolled opening (without flow-control gates) of that size would result in high-tide elevations within the marsh which could cause flooding of a few residential yards along Phillips Road during astronomic tides. As it was known that the culvert would be fitted with flow-control gates, this size was selected as the largest to be analyzed. The gates could be closed slightly to reduce the flow from maximum, or could be opened fully if the resulting high tide elevations were less than predicted by the hydraulic model.

The existing 48-inch diameter culvert beneath the Canal Service Road has an invert elevation of -2.71 feet NGVD on the Canal-side and -2.05 feet NGVD on the marsh side, and the existing 48-inch diameter culvert beneath Scusset Beach Road has an invert elevation of -2.71 feet NGVD on the Canal-side and -2.45 feet NGVD on the marsh-side. The tidal channel has silted in such that it has an invert elevation of about 0 feet NGVD between the roads and about -1.0 feet

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[3] The "invert" elevation of a culvert or channel refers to the bottom elevation of the surface that is in contact with the flow.

NGVD on the marsh-side of the Scusset Beach Road culvert. The invert elevation of the tidal channel above Scusset Beach Road is variable. The invert elevation is about -1.0 feet NGVD at the end of the riprapped man-made section, which extends about 1,100 feet from the Canal; about -3.0 feet NGVD at Transect 1, which is about 1,600 feet from the Canal; and about -1.0 feet NGVD at Transect 2, which is about 3,600 feet from the Canal.

In order to determine the optimum invert elevation of the tidal channel for the alternatives to be analyzed in detail, the hydraulic model was used to evaluate the affect that deepening the inlet tidal channel to elevation -4.0 feet NGVD would have on high and low tide elevations within the marsh. The model was used to analyze the affect of deepening the inlet channel: 1) to the end of the man-made section; 2) to Transect 1; and 3) to Transect 2. The analysis concluded that deepening the channel under those scenarios would not significantly increase water surface elevations in the marsh at high tide, and would not decrease water surface elevations in the marsh at low tide beyond the point of channel deepening. Therefore, it was determined that deepening the channel to elevation -4.0 feet NGVD was not warranted.

The hydraulic model was then used to analyze the effect of deepening the inlet tidal channel only as required to improve hydraulic conveyance. The analysis assumed that the Canal Service Road culvert would be installed with invert elevations of -2.71 feet NGVD on the Canal-side and -2.45 feet NGVD on the marsh-side, the Scusset Beach Road culvert would be installed level (since flow is in both directions) with an invert elevation of -2.45 feet NGVD, the channel between the culverts would be deepened to -2.45 feet NGVD, and the channel upstream of Scusset Beach Road would be deepened under three scenarios: 1) to Transect 1 at a slope of 0.23% (the slope constructed in the mid-1930's) from elevation -2.45 feet NGVD at Scusset Beach Road; 2) to Transect 1 at elevation -2.45 feet NGVD; and 3) to Transect 2 at elevation -2.45 feet NGVD. The analysis concluded that the first scenario was the most logical since it reduced low tide elevations at Transect 2 approximately 0.5 feet. Deepening the channel to elevation -2.45 feet further into the marsh, as described under the second and third scenarios, did not decrease water surface elevations in the marsh at low tide beyond the point of channel deepening.

Therefore, it was determined that culverts would be installed with the invert elevations modeled above, the channel between the roads would be deepened to elevation -2.45 feet NGVD, and the channel would slope upward at 0.23% from elevation -2.45 feet NGVD at the Scusset Beach Road culvert to the end of the man-made section, which is about 1,100 feet from the Canal.

6.3 CONSIDERED ALTERNATIVES

Once the sensitivity analysis was completed, several alternatives were considered ranging from culvert openings of 6-feet high by 6-feet wide to 10-feet high by 40-feet wide. The criteria used to select alternatives for further consideration were the resulting high tide elevation at

Transect 2, as estimated by the hydraulic model, and the estimated relative cost, as determined by the study team. In order to be selected for further consideration, an alternative had to produce a high tide elevation for the least cost. The seven alternatives selected for further consideration are shown in Table 2. The elements common to all alternatives were:

- Replace the existing 48-inch diameter culvert beneath the Canal Service Road and the 48-inch diameter culvert beneath Scusset Beach Road with larger culverts in order to increase the amount of salt water entering the marsh.
- Install the Canal Service Road culvert at an invert elevation of -2.7 feet NGVD on the Canal-side (same as existing) and -2.45 feet NGVD on the marsh-side.
- Install flow control gates on the Canal Service Road culvert which could be closed prior to predicted severe storm events.
- Install the Scusset Beach Road culvert level with an invert elevation of -2.45 feet NGVD.
- Deepen the channel between the roads to elevation -2.45 feet NGVD.
- Deepen the channel above the Scusset Beach Road culvert to slope upward at 0.23% from elevation -2.45 feet NGVD at the Scusset Beach Road culvert to the end of the man-made section, which is about 1,100 feet from the Canal.
- Widen the 210-foot long man-made channel between the roads and the 600-foot long man-made channel upstream of Scusset Beach Road as needed to accommodate the larger culverts.
- Excavate the side slopes of the channel at 1-foot vertical to 2-feet horizontal.
- Install riprap on the widened channel bottom for scour protection and riprap on the slopes for slope stability.
- Install a one-way flap gate on the downstream side of the existing 24-inch culvert beneath the dirt road extension of Pilgrim Road to prevent the flow of tidal water to the wetland upstream of the dirt road, and remove siltation on the downstream side of the Pilgrim Road culvert to allow installation of the flap gate. This culvert is shown on Figure 2.

Table 2

CONSIDERED ALTERNATIVES

6-foot high by 6-foot wide culvert with a 6-foot wide channel

6-foot high by 8-foot wide culvert with an 8-foot wide channel

6-foot high by 12-foot wide culvert with a 12-foot wide channel

6-foot high by 16-foot wide culvert with a 16-foot wide channel

10-foot high by 20-foot wide culvert with a 30-foot wide channel

6-foot high by 40-foot wide culvert with a 40-foot wide channel

10-foot high by 40-foot wide culvert with a 40-foot wide channel

SECTION 7

EVALUATION OF ALTERNATIVES

7.1 INTRODUCTION

The characteristics of each alternative were evaluated to ensure that there were no engineering, economic, or environmental factors which would eliminate an alternative.

7.2 GEOTECHNICAL ANALYSIS

A geotechnical analysis was performed to determine the structural characteristics of the soils in the vicinity of proposed improvements at the southern end of the marsh. Soil borings were taken in the vicinity of the Canal Service Road culvert, the Scusset Beach Road culvert, and the existing man-made channel north of Scusset Beach Road. Soil samples were taken at representative intervals, and the samples were analyzed in a lab to determine the mechanical properties of the soil. Those properties were used to design the foundation for various culvert alternatives, and for the recommended alternative. The boring at the Canal Service Road showed approximately 9 feet of loose sand underlain by approximately 7 feet of organic silt underlain by approximately 5 feet of medium dense sand. The boring at Scusset Beach Road showed approximately 16 feet of sand underlain by approximately 2 feet of organic silt. The results of the geotechnical analysis showed that all culvert alternatives could be constructed, provided that compressible soils containing organic material are removed to a depth of 3 feet below the bottom of the culvert, and bedding material is placed to support the culverts. Appendix D contains the complete report of the geotechnical analysis.

7.3 GROUNDWATER MODEL AND ANALYSIS

7.3.1 Introduction

A groundwater analysis was performed to assess the potential impact that increased high tide stages in Sagamore Marsh, resulting from the installation of larger culverts, would have on nearby septic systems and on the potential for drawdown of salty water from the marsh to nearby water supply wells. The analysis was performed by the US Geological Survey (USGS) under contract to the Corps. The USGS was selected because of their expertise in monitoring, modeling, and analyzing groundwater flow, their regional expertise of studying groundwater on Cape Cod, and their experience working in marsh environments.

The principal components of the groundwater analysis were the research of existing data, collection of site specific data, and analysis of the data. Appendix E contains the complete report of the groundwater model and analysis.

7.3.2 Hydrogeology[4]

The USGS used data from regional studies on the geology of the area and groundwater flow in the area to prepare their plan of study for this site. The Sagamore Marsh area lies within the Plymouth-Carver aquifer, which encompasses an area of about 140 square miles in Plymouth and Barnstable County. Land surface elevations range from 250 feet above sea level inland to sea level along the coast. Groundwater levels in the aquifer range from about 125 feet above sea level to the northwest of the Sagamore Marsh area to sea level along the coast, producing a strong gradient of flow from northwest to southeast in the Sagamore Marsh area. In the vicinity of Sagamore Marsh, groundwater levels range from about 6 feet above sea level near the western edge of the marsh to sea level at the coast.

The USGS obtained site-specific information on geology, groundwater flow, and surface water flow by installing twelve drilled wells outside of the marsh, five drive points at the edge of the marsh, three drive points in the marsh, three tidal channel gages in the marsh, and one drive point on the Cape Cod Bay-side of the dune east of Phillips Road. The locations of the groundwater wells and tidal channel gages used in the groundwater analysis are shown in Figure 8. The installation of wells and gages was planned to ensure that there would be minimal impact to wetland resources.

The stratigraphy (or layering) of the glacial marsh sediments was observed and recorded during installation of the wells, and was subsequently confirmed using geophysical logging. Four major hydrogeologic units were observed in the glacial sediments: a fine-grained confining unit consisting of brown fine silt and sandy clay; underlying fine to coarse brown sand with some gravel; interlayered gravel, sand, silt, and some clay; and dense gray fine silty sand. The fine to coarse brown sand constitutes an important aquifer in the Sagamore Marsh area. Marine sediments overlie the glacial sediments along the coast. These sediments consist of fine to medium gray sand underlain by silt and marine clay. Marsh deposits near the southern end of the marsh consist of gray clayey peat underlain by brown fibrous peat. Marsh sediments near the eastern perimeter of the marsh are finer-grained than at the southern end, and consist of gray clayey peat underlain by marine clay.

Though most of the regional flow system is unconfined, the low vertical and horizontal hydraulic conductivity of the fine-grained glacial sediments along the western edge of the marsh and of the fine-grained marsh sediments cause confining conditions beneath the marsh; for this reason, the regional flow system is referred to as a semi-confined flow

[4] "Hydrogeology" describes the geology and groundwater flow system in the area.

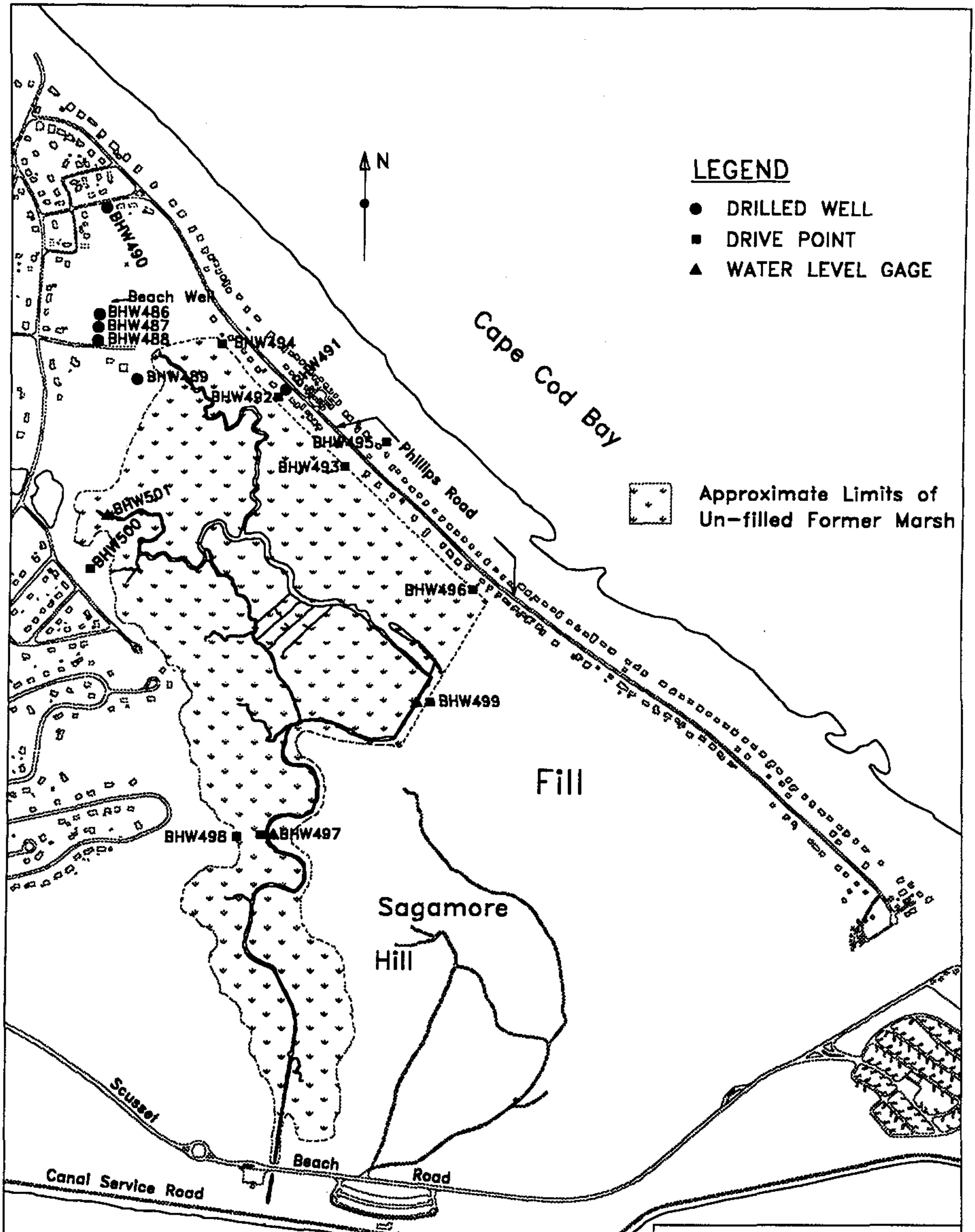


FIGURE 8

LOCATIONS OF GROUNDWATER WELLS AND TIDAL CHANNEL GAGES

SCALE: 1" = 1000'

system in the vicinity of the marsh. Unconfined conditions prevail within the marsh sediments themselves, beyond the western and northwestern extent of the confining deposits, and along the barrier beach on the northeastern side of the marsh; confined conditions prevail immediately beneath the marsh sediments; and semi-confined conditions prevail along the northwestern edge of the marsh.

A significant finding from the installation of the wells was that the finer-grained marsh sediments are about 20 feet thick in the middle of the marsh, and are underlain by coarser-grained sand that constitutes an aquifer beneath the marsh sediments. Groundwater flows from the northwest in an unconfined (water-table) aquifer to the vicinity of the marsh. Groundwater flows beneath the marsh where it is confined by the marsh sediments; this deep groundwater flows to the southeast and eventually discharges to Cape Cod Bay. Groundwater flow in the shallow part of the aquifer discharges along the marsh edges, as evidenced by numerous fresh-water springs and seeps found along the edge of the marsh.

Groundwater heads in the confined aquifer beneath the marsh were found to be one- to two-feet higher than the marsh surface, showing that groundwater beneath the marsh is under pressure and that there is a strong gradient pushing flow upward from the aquifer. Therefore, saltwater in the marsh and marsh tidal channels does not flow down into the aquifer.

7.3.3 Effect of Marsh Restoration on Septic Systems

It was found that there is a high groundwater table behind houses along the southwest side of Phillips Road. From the installation of drive points in that area, the depth to groundwater was found to be between 0.5 and 1.5 feet at the locations of the drive points. The effect of marsh restoration on septic systems was analyzed by measuring the tidal range in the marsh channels and the tidal pulse at the contact between the marsh sediments and the underlying fine sand aquifer in order to determine the effect that fluctuations in tidal channel stage had on groundwater levels. Tidal ranges in the marsh channels were measured at two locations using tidal channel gages fitted with pressure transducers, and tidal pulses in the sediments were measured adjacent to the channels in drive points fitted with pressure transducers. The two measurement locations are shown as BHW497 and BHW499 on Figure 8. BHW497, referred to as the "lower marsh", was located at Transect 2. BHW499, referred to as the "upper marsh", was located approximately 200 feet southwest of the 90-degree bend in the marsh channel. The drive points were located approximately 10 feet from the channel at each location.

It was found that the tidal range in the marsh channels was rapidly attenuated in the sediments. During the period of study, tidal ranges in the marsh channels were between 1.0 and 1.5 feet, whereas tidal pulses in the sediments adjacent to the channels were between 0.05 and 0.2 feet, with a mean range of 0.07 feet at BHW499 and 0.15 feet at BHW497. The data also indicate that tidal pulses in the aquifer beneath the marsh appeared to be in phase with tidal ranges in the marsh channels.

It should be noted that the tidal "pulse" measured in the drive points in the sediments is not a fluctuation of tidal water, but rather a response to the variation in pressure exerted by the varying level of water in the marsh channel. Deeper water in the marsh channel at high tide exerts a higher pressure on the water in the confined aquifer than shallower water in the marsh channel at low tide. The water level in the aquifer responds by rising and falling.

For reference, a drive point was also driven in the barrier beach on the east side of Phillips Road, approximately 100 feet from Cape Cod Bay. The tidal fluctuation in Cape Cod Bay was compared to the tidal pulse measured in the drive point to determine how the tidal fluctuation in Cape Cod Bay was transmitted to the water-table aquifer beneath the beach. It was found that even the large tidal fluctuation in Cape Cod Bay was rapidly attenuated in the aquifer. During the period of study, mean daily tide ranges in Cape Cod Bay were on the order of 9 feet, while mean daily tidal pulses in the unconfined aquifer beneath the barrier beach were on the order of 0.5 feet, compared to a mean groundwater range of 0.05 feet on the marsh-side of the barrier beach. The data also indicate that tidal pulses in the aquifer beneath the barrier beach appeared to be in phase with the tide in Cape Cod Bay.

To estimate the effect that marsh restoration would have on groundwater adjacent to the marsh, an analytical solution was used which relates fluctuations in tidal water bodies to the corresponding cyclic groundwater levels in adjacent aquifers. The formula relates the two fluctuations through the diffusivity of the aquifer, the distance from the tidal water body, and the tidal period. In this case, the tidal water body was the marsh channel, and the tidal period was 0.51 days. From the measured fluctuations, the diffusivity of the marsh sediments, which is the ratio of aquifer transmissivity to storativity, was calculated to be 170 ft^2/day at the upper marsh site and 380 ft^2/day at the lower marsh site. This indicates that sediments at the lower marsh site are slightly more conductive to groundwater flow than those at the upper marsh site. Based on the lithology observed during installation of the drive points and on published values, the diffusivity of the fine sand aquifer which underlies the marsh sediments was estimated to be 225,000 ft^2/day at both the upper and lower marsh sites, which indicates that the fine sand aquifer is much more conductive to groundwater flow than the marsh sediments.

The existing and proposed tide ranges in the tidal channels were then used to estimate the effect that marsh restoration would have on the tidal-induced groundwater ranges in both the marsh sediments and in the fine sand aquifer. The tide ranges were those predicted by the hydraulic model to occur at the upper and lower marsh sites approximately two times per month. For proposed conditions, the maximum proposed tide range, which occurs for the largest culvert alternative (10-feet high by 40-feet wide), was used in the analysis.

Tables 3a and 3b show the results of the analysis. Table 3a shows the existing and maximum predicted tidal-induced groundwater ranges in the marsh sediments, and Table 3b shows the existing and maximum predicted tidal-induced groundwater ranges in the underlying fine sand aquifer.

Table 3a

EXISTING AND PREDICTED TIDAL-INDUCED GROUNDWATER RANGES

Marsh Sediments

Location	Diffusivity (sq. ft./day)	Existing Mean Tide Range in the Tidal Channel (ft)	Maximum Predicted Tide Range in the Tidal Channel for the 10-foot high by 40-foot wide culvert (ft)	Distance from Tidal Channel (ft)	Existing Mean Tidal-induced Groundwater Range (ft)	Maximum Predicted Tidal-induced Groundwater Range for the 10-foot high by 40-foot wide culvert (ft)
BHW499 (Upper Marsh)	170	1.3	2.3	10	0.19	0.34
				25	0.01	0.02
				50	0.00	0.00
BHW497 (Lower Marsh)	380	1.3	2.3	10	0.36	0.64
				25	0.05	0.10
				50	0.00	0.00

Table 3b

EXISTING AND PREDICTED TIDAL-INDUCED GROUNDWATER RANGES
Underlying Fine Sand Aquifer

Location	Diffusivity (sq. ft./day)	Existing Mean Tide Range in the Tidal Channel (ft)	Maximum Predicted Tide Range in the Tidal Channel for the 10-foot high by 40-foot wide culvert (ft)	Distance from Tidal Channel (ft)	Existing Mean Tidal-induced Groundwater Range (ft)	Maximum Predicted Tidal-induced Groundwater Range for the 10-foot high by 40-foot wide culvert (ft)
BHW499 (Upper Marsh)	225000	0.06	0.106	10	0.06	0.10
				25	0.05	0.09
				50	0.05	0.08
				100	0.04	0.06
				200	0.02	0.04
				400	0.01	0.01
BHW497 (Lower Marsh)	225000	0.17	0.301	10	0.16	0.29
				25	0.15	0.26
				50	0.13	0.23
				100	0.10	0.18
				200	0.06	0.11
				400	0.02	0.04

The tables show that tidal-induced groundwater ranges are small under existing conditions, and remain small for even the maximum proposed tide levels for the largest culvert alternative. The back yards of houses along Phillips Road are typically 400 to 900 feet from the tidal channel, with a few back yards approximately 150 feet from the tidal channel at the northeastern end of the marsh. The calculated results for existing conditions are consistent with tidally-induced groundwater ranges observed during the period of study in drive points installed in the sand aquifer at the marsh edge at two locations behind houses along Phillips Road. There was no discernible tidal fluctuation in drive point BHW492 at the northeastern end of the marsh approximately 125 feet from the tidal channel, and the mean tide range in drive point BHW496 at the southeastern end of the marsh approximately 660 feet from the tidal channel was about 0.03 feet. These drive points are shown on Figure 8.

The analysis also indicates that, given the small tidal fluctuations observed in the aquifer and the rapid attenuation of tidal pulses in the marsh sediments, the magnitude of any tidally-induced groundwater fluctuations in the vicinity of septic systems would be significantly smaller than tidal pulses originating from Cape Cod Bay, and smaller than fluctuations due to precipitation events. During the period of study, groundwater levels in the two drive points discussed above were found to increase during a rainfall event about 0.25 feet at the southeastern edge of the marsh and 1.1 feet at the northeastern edge.

In addition, the analysis concluded that increased high-tide levels on the surface of the marsh are not expected to result in an increase in groundwater levels, since the small increase in the depth of water on the marsh would be rapidly attenuated in the marsh sediments, due to the low permeability of the marsh sediments.

In summary, the increased high-tide levels resulting from the installation of larger culverts is not expected to have any impact on septic systems adjacent to the marsh. Groundwater levels are not expected to increase more than 0.1 to 0.2 feet (1.2 to 2.4 inches) immediately adjacent to the marsh channels, and significantly less away from the channels. Leach fields in Bourne and Sandwich were required to be installed with a three-, four-, or five-foot separation between the water table and the bottom of the leach field, depending on the regulation that was in place at the time of construction. The small increase in groundwater levels shown above will not impact the performance of leach fields which meet the separation requirements.

7.3.4 Effect of Marsh Restoration on the Salinity of Water Supply Wells

The effect of marsh restoration on the salinity of the North Sagamore Water District's "Beach Well" and the Department of Environmental Management's (DEM) wells at Scusset Beach State Park was analyzed by performing an aquifer test on the Beach Well, and by developing a numerical model of groundwater flow in the vicinity of Sagamore Marsh.

A five-day aquifer test was performed to determine the response of the aquifer near the marsh to pumping at the North Sagamore Water District's Beach Well, and to determine the hydraulic properties of the aquifer near the marsh. The aquifer test was performed from June 1-6, 1995. The well was pumped continuously for five days at an average rate of 480 gallons per minute, and drawdown[5] was measured in fourteen nearby observation wells, including the supply well.

After 5 days of pumping, drawdown at the Beach Well was 17.5 feet below the nonpumping (static) water level, and drawdowns in wells screened in the same aquifer as the Beach Well at distances of 100, 183, 280, 491, 725, and 1450 feet from the Beach Well were 4.92, 4.05, 3.52, 3.18, 1.67, and 0.37 feet respectively. Drawdown was not measured at the DEM wells, which are approximately 6,700 feet southeast of the Beach Well. The wells are sealed and pump to a pressurized holding tank, and it was known that pumping of the Beach Well would not affect groundwater levels at that distance.

The results of the aquifer test were used to provide information on the characteristics of the glacial sand aquifer for input to a numerical groundwater flow model of the Sagamore Marsh area. The results of the numerical model indicated that the zone of contribution to the Beach Well extends from the well northwesterly toward Great Herring Pond, meaning that the flow of fresh water to the well comes mainly from the northwest. This was consistent with prior USGS studies, which showed that there is a strong hydraulic gradient from Great Herring Pond, southeasterly, toward Cape Cod Bay.

The model simulated three scenarios: (1) the average pumping rate for the Beach Well for 1994 (which was the most recent year of complete records and was typical) and the existing tidal stages within the marsh, (2) the average pumping rate for the Beach Well for 1994 and increased tidal stages within the marsh based on the largest culvert alternative, and (3) a higher pumping rate assuming that the Beach Well would supply all of the water supplied in 1994 by the North Sagamore Water District's two wells, the Black Pond Well and the Beach Well, coupled with the increased tidal stages within the marsh based on the largest culvert alternative. The model showed that the increased tidal stages within the marsh based on the largest culvert alternative would have little effect on the location of the zone of contribution to

[5] "Drawdown" refers to the lowering of the water level if measured in a water table aquifer, or the decrease in hydraulic head if measured in a confined aquifer.

the well. Groundwater flow from the confined aquifer beneath the marsh to the well was not induced by pumping of the Beach Well in any of the model simulations.

In summary, the primary direction of groundwater flow is from northwest to southeast, with groundwater flowing from higher elevations inland and discharging to the coast. Also, there is a thick confining layer of fine-grained marsh sediments which produces an upward gradient of flow from the confined aquifer beneath Sagamore Marsh. Because the Beach Well is located up-gradient from Sagamore Marsh, and because of the upward gradient of flow from the confined aquifer beneath the marsh, increased tidal stages in the marsh resulting from even the largest culvert alternative are not expected to have any effect on the salinity of the Beach Well.

There was very little information available on the DEM wells. Water levels were not measured at the wells since they are sealed and pump to a pressurized holding tank. Using information on the pumping rate provided by the DEM, and assuming that the wells drew groundwater from the same zone in the model as the Beach Well, the model was used to simulate pumping of the DEM wells. The model showed that under existing conditions, the wells draw water from the confined aquifer that lies beneath Sagamore Marsh. As stated in Section 7.3.2, groundwater flows from the northwest in an unconfined (water-table) aquifer to the vicinity of the marsh. Groundwater flows beneath the marsh where it is confined by the marsh sediments; this deep groundwater flows to the southeast and eventually discharges to Cape Cod Bay. Groundwater heads in the confined aquifer beneath the marsh were found to be one- to two-feet higher than the marsh surface, showing that groundwater beneath the marsh is under pressure and that there is a strong gradient pushing flow upward from the aquifer. Therefore, saltwater in the marsh and marsh tidal channels does not flow down into the aquifer. Therefore, increased tidal stages in the marsh resulting from even the largest culvert alternative are not expected to have any effect on the salinity of the DEM wells.

7.4 EFFECT OF RESTORATION ON FLOODING POTENTIAL

The hydraulic model was used to predict high tide elevations at Transect 2 in the marsh for each of the culvert alternatives for various tide levels in the Cape Cod Canal. High tide levels above Transect 2, i.e. at Transects 4-6, were about 0.1 foot lower than the high tide levels at Transect 2. These values are shown in Table 4 for existing conditions and for the seven alternatives (in Table 4 and hereafter, the alternatives will be referred to using a notation of 6'Hx6'W for the 6-foot high by 6-foot wide culvert, etc).

The hydrologic analysis in Appendix B calculated the increase in water level in Sagamore Marsh which occurs during storm events due storage of freshwater runoff resulting from rainfall events. The increase was calculated for storms with rainfall frequencies of 1-, 10-, 50-, and 100-years. The stage increases, along with the associated peak rates of inflow, are shown in Table 5.

Table 4

EXISTING AND PREDICTED TIDE LEVELS WITHIN SAGAMORE MARSH

Frequency of Tide Level in Canal	High Tide Level in Canal FT NGVD	High Tide Level at Transect 2							
		Existing culvert FT NGVD	6'Hx6'W culvert FT NGVD	6'Hx8'W culvert FT NGVD	6'Hx12'W culvert FT NGVD	6'Hx16'W culvert FT NGVD	10'Hx20'W culvert FT NGVD	6'Hx40'W culvert FT NGVD	10'Hx40'W culvert FT NGVD
8 x per month astronomic	4.95	2.9	3.2	3.2	3.2	3.3	3.5	3.6	3.7
2 x per month astronomic	5.6	3.0	3.2	3.3	3.4	3.5	3.7	3.9	4.0
Maximum astronomic	6.5	3.0	3.3	3.4	3.5	3.6	3.9	4.1	4.3
1-year storm	6.9	3.0	3.3	3.4	3.5	3.6	4.0	4.2	4.4
10-year storm	8.3	3.3	3.8	3.9	4.1	4.3	5.0	5.2	5.6
50-year storm	9.9	3.4	3.8	4.0	4.3	4.4	5.3	5.4	5.9
100-year storm	10.4	3.4	3.9	4.1	4.5	4.6	5.4	5.5	6.2

Table 5

INCREASE IN MARSH WATER SURFACE ELEVATION DURING STORM EVENTS DUE TO STORAGE OF RAINFALL AND RUNOFF

Frequency of Event	Stage Increase (feet)	Peak Inflow (cfs)
1-year rainfall	0.2	30
10-year rainfall	0.3	90
50-year rainfall	0.7	200
100-year rainfall	0.8	230

The high tide levels shown in Table 4 were added to the runoff values shown in Table 5 to produce the water surface elevations shown in Tables 6a-d for existing conditions and for the seven alternatives. The water levels shown in Tables 6a-d are for culvert openings without flow control gates. All proposed alternatives will incorporate flow control gates to exclude high tide elevations above those required for saltmarsh restoration. The water levels shown in Tables 6a-d also assume that storm water runoff is coincident with high tide in the marsh. Flow control gates could be closed at low tide in the marsh prior to a storm to maximize the area for storage of rainfall and freshwater runoff, which would reduce water levels in the marsh below those shown in Tables 6a-d. The existing culverts do not have flow control gates. Therefore, under existing conditions, there is no way to maximize the area for storage of rainfall and runoff within the marsh, whereas flow control gates would allow such an operation.

Tables 6a-d shows the greater risk of flooding yards during extreme rainfall events associated with the largest alternatives than is associated with the smallest alternatives. The largest alternatives would have to be operated more stringently than the smallest alternatives to minimize that risk. From Tables 4 & 6a-d, the largest difference in water levels occurs between the 6'Hx16'W alternative and the 10'Hx20'W alternative. Using those two alternatives as a break-point, it was concluded that the primary flow control gates for the four smallest alternatives could either be automatic tide gates or electric sluice gates. Automatic tide gates would close when the tide level in the Cape Cod Canal reached a prescribed elevation. Electric sluice gates would require operation by an attendant, but would have a lower initial cost. It was concluded that the primary flow control gates for the three largest alternatives would be automatic tide gates, because of the need for more frequent gate closing, and because of the increased risk of flooding if gates were not closed as required.

As part of the topographic survey performed for this study, elevations were surveyed at every house bordering the marsh with yard elevations below elevation 10.0 feet NGVD. At those locations, there were three elevations surveyed: 1) the elevation of the first floor; 2) the elevation of the low point at the house; and 3) the low point of the "useable" or maintained yard on the marsh-side of the house. The results of the topographic survey are shown in Table A-1 of Appendix A. From the hydraulic analysis and the topographic survey, it was concluded that all alternatives could be implemented without impacting houses or yards, provided that flow control gates were included in the project to exclude high tide levels significantly greater than those required for saltmarsh restoration.

7.5 EFFECT OF RESTORATION ON NAVIGATION

The hydraulic analysis concluded that the change in the velocity of water leaving the marsh through larger culverts and entering the Cape Cod Canal, compared to existing conditions, would be small for all alternatives. The highest velocity at the Canal Service Road culvert was predicted to be 5 feet per second, and velocities did not vary significantly between alternatives. None of the culvert alternatives are expected to adversely impact navigation in the Cape Cod Canal.

Tables 6a-b

EXISTING AND PREDICTED EXTREME STORM WATER LEVELS WITHIN SAGAMORE MARSH (WITHOUT FLOW CONTROL STRUCTURES)

Frequency of Tide Level in Canal	Water Level at Transect 2 with 1-year Runoff (0.2') (assuming peak runoff is coincident with high tide)							
	Existing culvert FT NGVD	6'Hx6'W culvert FT NGVD	6'Hx8'W culvert FT NGVD	6'Hx12'W culvert FT NGVD	6'Hx16'W culvert FT NGVD	10'Hx20'W culvert FT NGVD	6'Hx40'W culvert FT NGVD	10'Hx40'W culvert FT NGVD
8 x per month astronomic	3.1	3.4	3.4	3.4	3.5	3.7	3.8	3.9
2 x per month astronomic	3.2	3.4	3.5	3.6	3.7	3.9	4.1	4.2
Maximum astonomic	3.2	3.5	3.6	3.7	3.8	4.1	4.3	4.5
1-year storm	3.2	3.5	3.6	3.7	3.8	4.2	4.4	4.6
10-year storm	3.5	4.0	4.1	4.3	4.5	5.2	5.4	5.8
50-year storm	3.6	4.0	4.2	4.5	4.6	5.5	5.6	6.1
100-year storm	3.6	4.1	4.3	4.7	4.8	5.6	5.7	6.4

Frequency of Tide Level in Canal	Water Level at Transect 2 with 10-year Runoff (0.3') (assuming peak runoff is coincident with high tide)							
	Existing culvert FT NGVD	6'Hx6'W culvert FT NGVD	6'Hx8'W culvert FT NGVD	6'Hx12'W culvert FT NGVD	6'Hx16'W culvert FT NGVD	10'Hx20'W culvert FT NGVD	6'Hx40'W culvert FT NGVD	10'Hx40'W culvert FT NGVD
8 x per month astronomic	3.2	3.4	3.4	3.4	3.6	3.8	3.9	4.0
2 x per month astronomic	3.3	3.5	3.6	3.7	3.8	4.0	4.2	4.3
Maximum astonomic	3.3	3.6	3.7	3.8	3.9	4.2	4.4	4.6
1-year storm	3.3	3.6	3.7	3.8	3.9	4.3	4.5	4.7
10-year storm	3.6	4.1	4.2	4.4	4.6	5.3	5.5	5.9
50-year storm	3.7	4.1	4.3	4.6	4.7	5.6	5.7	6.2
100-year storm	3.7	4.2	4.4	4.8	4.9	5.7	5.8	6.5

Tables 6c-d

EXISTING AND PREDICTED EXTREME STORM WATER LEVELS WITHIN SAGAMORE MARSH (WITHOUT FLOW CONTROL STRUCTURES)

Frequency of Tide Level in Canal	Water Level at Transect 2 with 50-year Runoff (0.7') (assuming peak runoff is coincident with high tide)							
	Existing culvert FT NGVD	6'Hx6'W culvert FT NGVD	6'Hx8'W culvert FT NGVD	6'Hx12'W culvert FT NGVD	6'Hx16'W culvert FT NGVD	10'Hx20'W culvert FT NGVD	6'Hx40'W culvert FT NGVD	10'Hx40'W culvert FT NGVD
8 x per month astronomic	3.6	3.9	3.9	3.9	4.0	4.2	4.3	4.4
2 x per month astronomic	3.7	3.9	4.0	4.1	4.2	4.4	4.6	4.7
Maximum astonomic	3.7	4.0	4.1	4.2	4.3	4.6	4.8	5.0
1-year storm	3.7	4.0	4.1	4.2	4.3	4.7	4.9	5.1
10-year storm	4.0	4.5	4.6	4.8	5.0	5.7	5.9	6.3
50-year storm	4.1	4.5	4.7	5.0	5.1	6.0	6.1	6.6
100-year storm	4.1	4.6	4.8	5.2	5.3	6.1	6.2	6.8

Frequency of Tide Level in Canal	Water Level at Transect 2 with 100-year Runoff (0.8') (assuming peak runoff is coincident with high tide)							
	Existing culvert FT NGVD	6'Hx6'W culvert FT NGVD	6'Hx8'W culvert FT NGVD	6'Hx12'W culvert FT NGVD	6'Hx16'W culvert FT NGVD	10'Hx20'W culvert FT NGVD	6'Hx40'W culvert FT NGVD	10'Hx40'W culvert FT NGVD
8 x per month astronomic	3.7	4.0	4.0	4.0	4.1	4.3	4.4	4.5
2 x per month astronomic	3.8	4.0	4.1	4.2	4.3	4.5	4.7	4.8
Maximum astonomic	3.8	4.1	4.2	4.3	4.4	4.7	4.9	5.1
1-year storm	3.8	4.1	4.2	4.3	4.4	4.8	5.0	5.2
10-year storm	4.1	4.6	4.7	4.9	5.1	5.8	6.0	6.4
50-year storm	4.2	4.6	4.8	5.1	5.2	6.1	6.2	6.7
100-year storm	4.2	4.7	4.9	5.3	5.4	6.2	6.3	7.0

SECTION 8

COMPARISON OF ALTERNATIVES

8.1 GENERAL

The seven alternatives for restoring saltmarsh and estuarine habitat at Sagamore Marsh were compared to the existing condition of the marsh, and to each other, to identify the recommended alternative. Thereafter, study efforts focused on optimizing the design features of the recommended alternative.

As stated in Section 5.3, the hydraulic model was used to predict water surface elevations which would occur eight times per month at each of the surveyed cross-sections for each of the alternatives. There were seven culvert alternatives analyzed in detail ranging in size from 6-feet high by 6-feet wide to 10-feet high by 40-feet wide.

The water surface elevations predicted by the hydraulic model were then used to estimate the area inundated by salt water eight times per month for each culvert size. The area of existing saltmarsh and estuarine habitat was subtracted from the total area inundated by salt water eight times per month for each culvert size, resulting in the estimated net acres of saltmarsh and estuarine habitat expected to be restored by each alternative. These values are shown in Table 7.

Table 7

ESTIMATED ACRES RESTORED BY EACH ALTERNATIVE

Alternative	Acres Restored
6'H x 6'W Culvert, 6'W Channel	37
6'H x 8'W Culvert, 8'W Channel	38
6'H x 12'W Culvert, 12'W Channel	50
6'H x 16'W Culvert, 16'W Channel	51
10'H x 20'W Culvert, 30'W Channel	71
6'H x 40'W Culvert, 40'W Channel	73
10'H x 40'W Culvert, 40'W Channel	74

8.2 INCREMENTAL ANALYSIS

An Incremental Analysis was performed to compare the seven alternatives in order to identify the recommended alternative. The Incremental Analysis identified the most cost-effective alternatives, and eliminated ineffective alternatives. Appendix C contains the complete Incremental Analysis.

As stated in Section 7.4, it was concluded that the primary flow control gates for the four smallest alternatives could either be automatic tide gates or electric sluice gates. Automatic tide gates would close when the tide level in the Cape Cod Canal reached a prescribed elevation. Electric sluice gates would require operation by an attendant, but would have a lower initial cost. Therefore, alternatives using both systems were carried forward in the analysis, which essentially added four alternatives to the analysis. Alternatives which use automatic tidegates for primary flow control incorporate electric sluice gates for backup closure. Alternatives which use electric sluice gates for primary flow control incorporate stop logs for backup closure.

The cost of each alternative was estimated to compare the alternatives. The costs included the first cost of construction, plans and specifications, construction management, operation and maintenance, and annualized replacements. Construction costs included the estimated quantities of excavation and backfill, size and length of culverts, size and number of electric sluice gates, size and number of stop logs and frames or size and number of automatic tide gates, construction and removal of temporary roads, removal and reconstruction of existing roads, and removal and replacement of guide rails. A construction cost contingency of 15% was used. Table 8 shows the estimated cost of each alternative.

The four smaller alternatives with automatic tidegates were dropped from further consideration, since they had higher first costs, higher annual operation and maintenance costs, and higher costs of annual replacements. The investment cost of the remaining seven alternatives were calculated by discounting the annual operation and maintenance costs and the cost of annual replacements to present worth. The investment cost of each alternative, along with the cost per acre of saltmarsh restored, is shown in Table 9.

In the Incremental Analysis, successive alternatives were compared to preceding alternatives in terms of additional cost per additional acre restored. Inefficient alternatives, which had a greater additional cost per additional acre restored than the succeeding alternative, were then eliminated from further consideration. Table 10 shows a summary of the results. The Incremental Analysis identified the 6'Hx12'W culvert alternative, with electric sluice gates for primary flow control, as the lowest marginal cost alternative. Factors which were considered when deciding whether to move beyond the lowest marginal cost alternative include the need to maintain adequate drainage of the marsh peat, which may be important for plant growth and productivity; the need to avoid the potential for impact to four-toed salamanders; and the incremental cost. Both drainage and the potential for impact to four-toed salamanders would be worse with alternatives larger than the 6'H x 12'W alternative.

Table 8

Cost of Alternatives

Alternative	Construction Cost Including Escalation & 15% Contingency	Planning, Engineering, & Design	Construction Management	Total First Cost	Annual Operation & Maintenance	Annual Replacements
6'H x 6'W Culvert, Sluicegates	$606,525	$90,979	$69,750	$767,254	$3,800	$0
6'H x 6'W Culvert, Tidegates	$745,968	$111,895	$85,786	$943,650	$4,000	$100
6'H x 8'W Culvert, Sluicegates	$709,779	$106,467	$81,625	$897,870	$4,300	$0
6'H x 8'W Culvert, Tidegates	$983,378	$147,507	$113,088	$1,243,973	$4,600	$100
6'H x 12'W Culvert, Sluicegates	$784,071	$117,611	$90,168	$991,850	$4,700	$0
6'H x 12'W Culvert, Tidegates	$1,238,712	$185,807	$142,452	$1,566,971	$5,000	$100
6'H x 16'W Culvert, Sluicegates	$979,800	$146,970	$112,677	$1,239,447	$5,100	$0
6'H x 16'W Culvert, Tidegates	$1,585,551	$237,833	$182,338	$2,005,722	$5,400	$200
10'H x 20'W Culvert, Tidegates	$2,197,241	$329,586	$252,683	$2,779,509	$6,000	$200
6'H x 40'W Culvert, Tidegates	$3,509,613	$526,442	$403,605	$4,439,660	$8,000	$400
10'H x 40'W Culvert, Tidegates	$4,143,589	$621,538	$476,513	$5,241,640	$9,000	$400

Table 9

ESTIMATED INVESTMENT COST AND COST PER ACRE RESTORED OF EACH ALTERNATIVE

Alternative	Acres Restored	Investment Cost	Cost/acre
6'H x 6'W Culvert, Electric Sluicegates, 6' W Channel	37	$ 815,800	22,049
6'H x 8'W Culvert, Electric Sluicegates, 8'W Channel	38	$ 952,800	25,074
6'H x 12'W Culvert, Electric Sluicegates, 12'W Channel	50	$ 1,051,900	21,038
6'H x 16'W Culvert, Electric Sluicegates, 16'W Channel	51	$ 1,304,600	25,580
10'H x 20'W Culvert, Automatic Tidegates, 30'W Channel	71	$ 2,858,800	40,265
6'H x 40'W Culvert, Automatic Tidegates, 40'W Channel	73	$ 4,547,000	62,288
10'H x 40'W Culvert, Automatic Tidegates, 40'W Channel	74	$ 5,241,640	70,833

Table 10

COMPARISON OF ALTERNATIVES - SUMMARY

Alternative	Acres Restored	Investment Cost	Cost/acre
6'H x 12'W Culvert, Electric Sluicegates, 12'W Channel	50	$ 1,051,900	21,038
10'H x 20'W Culvert, Automatic Tidegates, 30'W Channel	71	$ 2,858,800	40,265
10'H x 40'W Culvert, Automatic Tidegates, 40'W Channel	74	$ 5,241,640	70,833

The Incremental Analysis concluded that the recommended alternative is a 6-foot high by 12-foot wide culvert opening with a 12-foot wide (bottom width) channel, with electric sluice gates for primary means of flow control. That alternative is estimated to restore approximately 50 acres of saltmarsh. The area of expected saltmarsh restoration is shown in Figure 9.

Once the recommended alternative was identified, the hydraulic model was used to determine if high-tide elevations within the marsh, and thus the area of restoration, could be increased by widening the channel more than the proposed 12-foot bottom width. The analysis showed that, even for a 30-foot bottom width, the increase in high-tide elevation at Transect 2 was approximately 0.05 feet, which would not result in enough additional restoration to warrant the additional cost. Therefore widening beyond 12 feet was not warranted.

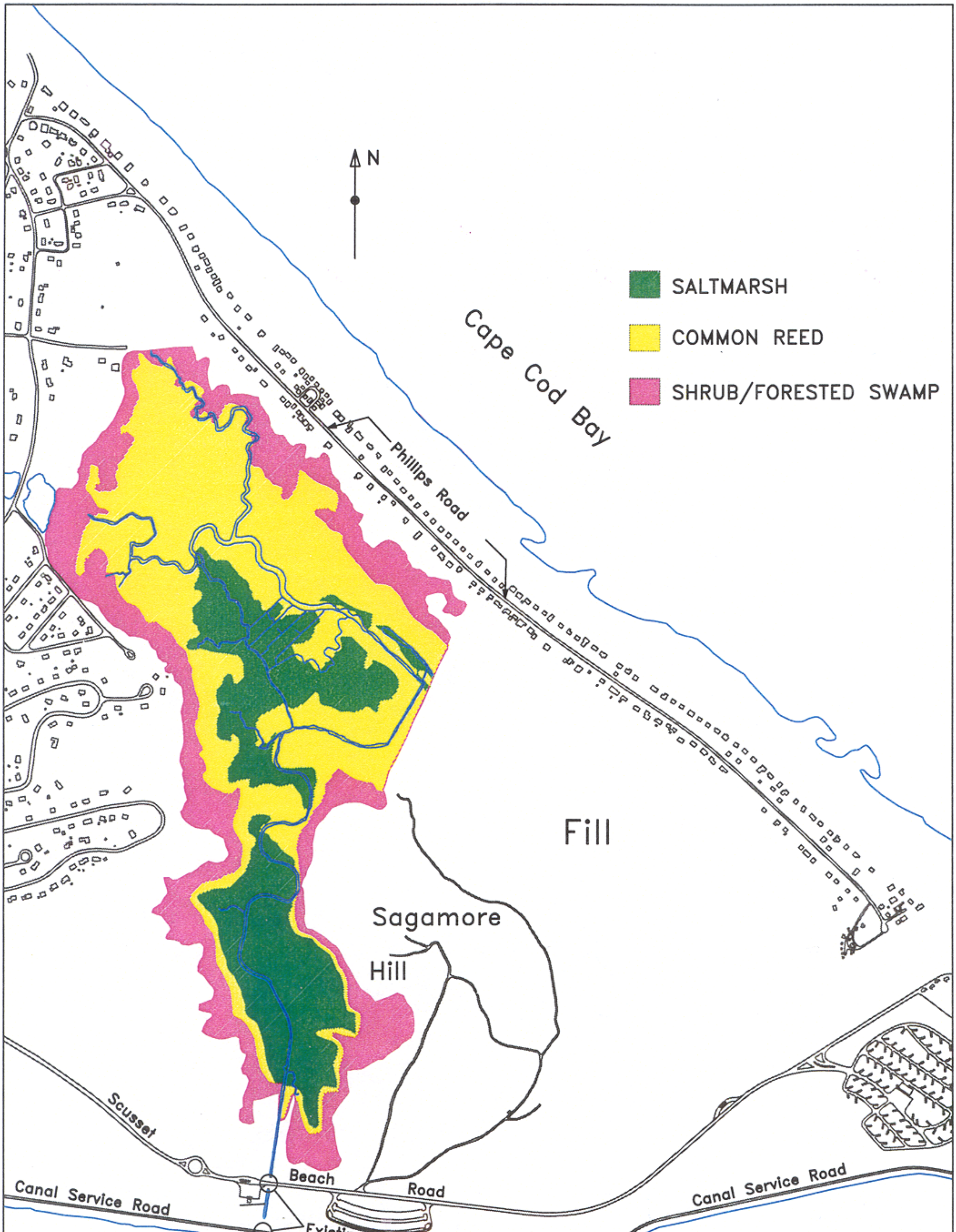


FIGURE 9
CONCEPTUAL AREA OF SALTMARSH RESTORATION
SCALE: 1" = 1000'

SECTION 9

RECOMMENDED ALTERNATIVE

9.1 INTRODUCTION

The recommended alternative has the following features:

- Replace each of the existing 48-inch diameter reinforced concrete culverts beneath the Canal Service Road and Scusset Beach Road with a 6-foot high by 12-foot wide reinforced concrete box culvert;

- Install the Canal Service Road culvert at an invert elevation of -2.7 feet NGVD on the Canal-side (same as existing) and -2.45 feet NGVD on the marsh-side, and install the Scusset Beach Road culvert level with an invert elevation of -2.45 feet NGVD;

- Deepen the existing man-made channel between the roads to elevation -2.45 feet NGVD to remove siltation, and deepen the existing channel above the Scusset Beach Road culvert to slope upward at 0.23% from elevation -2.45 feet NGVD at the Scusset Beach Road culvert to the end of the man-made section;

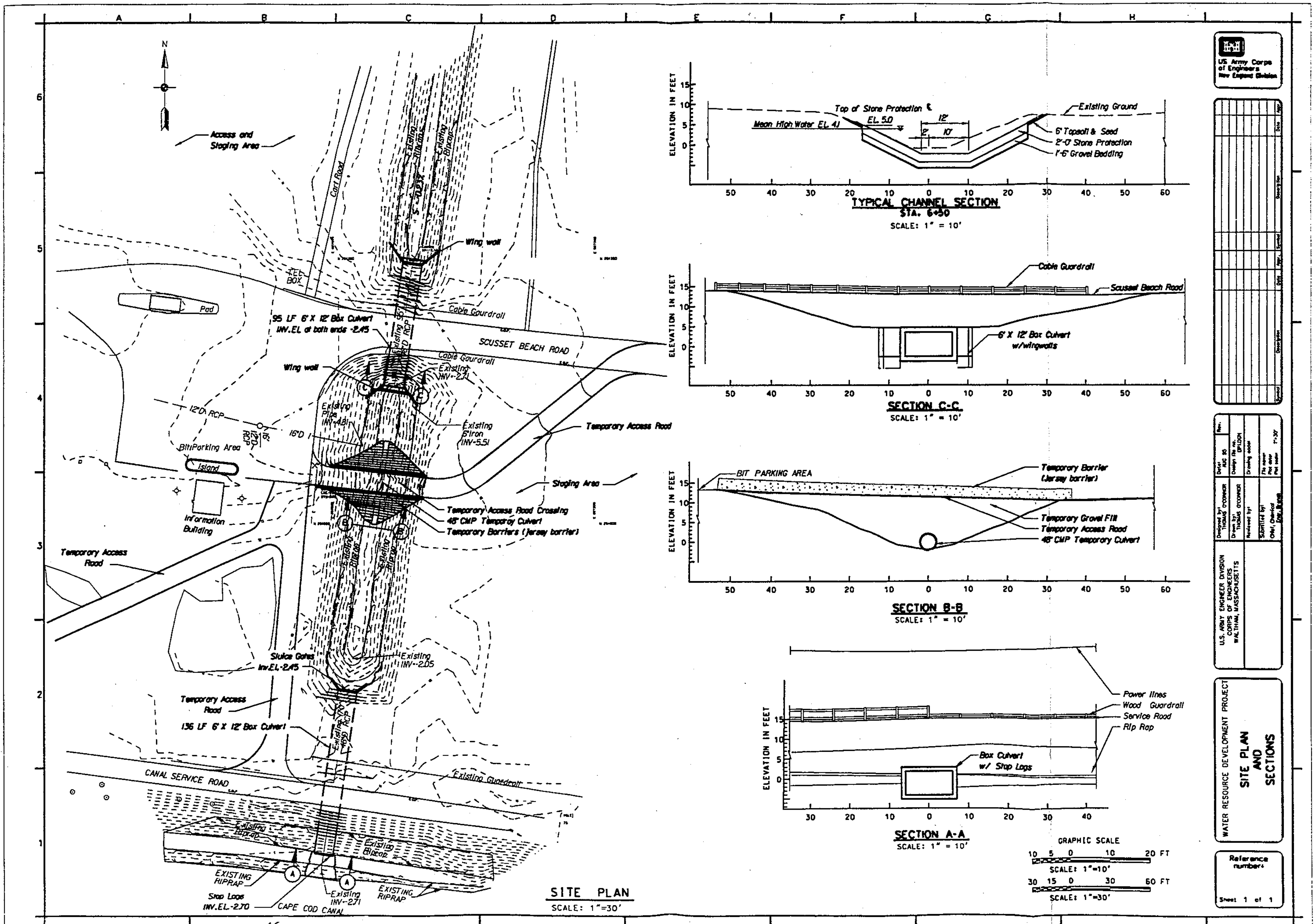
- Widen the existing 210-foot long man-made channel between the roads and the 600-foot long man-made channel upstream of Scusset Beach Road from an existing bottom width of 4 feet to a bottom width of 12 feet by excavating the east channel bank at a slope of 1-foot vertical to 2 feet horizontal, leaving the west channel bank undisturbed wherever possible;

- Excavate the side slopes of the channel at 1-foot vertical to 2-feet horizontal, install riprap on the widened channel bottom for scour protection, install riprap on the slopes up to elevation 5.0 feet NGVD for slope stability, and topsoil and seed the slope above that elevation;

- Install electric sluice gates on the marsh-side of the Canal Service Road culvert for primary flow control, and stop logs on the Canal side of the Canal Service Road culvert for backup closure;

- Install a one-way flap gate on the downstream side of the existing 24-inch culvert beneath the dirt road extension of Pilgrim Road to prevent the flow of tidal water to the wetland upstream of the dirt road, and remove siltation on the downstream side of the Pilgrim Road culvert to allow installation of the flap gate.

This plan will increase high tide elevations in the middle of the marsh 0.3 feet (about 3-1/2 inches) approximately eight times per month, and is estimated to restore approximately 50 acres of saltmarsh. Details of the recommended plan are shown on Sheet 1.



US Army Corps of Engineers New England Division
Access and Staging Area
Cart Road
Existing Riprap
Wing wall
TEL BOX
Pad
Cable Guardrail
95 LF 6' X 12' Box Culvert
INV.EL at both ends -2.45
SCUSSET BEACH ROAD
Existing INV-2.71
12'D RCP
Existing Pipe INV-4.81
Existing 6"iron INV-5.51
16'D
Temporary Access Road
BitiParking Area
Island
Staging Area
Information Building
Temporary Access Road Crossing
48" CMP Temporary Culvert
Temporary Barriers (jersey barrier)
Temporary Access Road
Sluice Gates INV.EL-2.45
Existing INV-2.05
136 LF 6' X 12' Box Culvert
CANAL SERVICE ROAD
Existing Guardrail
EXISTING RIPRAP
Stop Logs INV.EL-2.70
CAPE COD CANAL
Existing INV-2.71
SITE PLAN
SCALE: 1"=30'
ELEVATION IN FEET
Top of Stone Protection ℄
EL 5.0
Mean High Water EL 4.1
Existing Ground
6" Topsoil & Seed
2'-0" Stone Protection
1'-6" Gravel Bedding
TYPICAL CHANNEL SECTION
STA. 6+50
SCALE: 1" = 10'
Cable Guardrail
Scusset Beach Road
6' X 12' Box Culvert w/wingwalls
SECTION C-C
SCALE: 1" = 10'
BIT PARKING AREA
Temporary Barrier (Jersey barrier)
Temporary Gravel Fill
Temporary Access Road
48" CMP Temporary Culvert
SECTION B-B
SCALE: 1" = 10'
Power lines
Wood Guardrail
Service Road
Rip Rap
Box Culvert w/ Stop Logs
SECTION A-A
SCALE: 1" = 10'
GRAPHIC SCALE
SCALE: 1"=10'
SCALE: 1"=30'
U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS
WATER RESOURCE DEVELOPMENT PROJECT
SITE PLAN AND SECTIONS
Reference number:
Sheet 1 of 1

9.2 PRELIMINARY CONSTRUCTION SEQUENCE

A preliminary construction sequence is described below. Construction details will be developed during the preparation of plans and specifications. Sheet 1 shows the details of the recommended plan.

Construction will be carried out in a manner which minimizes the transport of silt from the work area to Sagamore Marsh and to the Cape Cod Canal. Haybales, silt fencing, and/or other erosion control measures will be placed prior to the start of construction. Vegetation will be cleared only as required to provide a staging area, an area for stockpiling equipment and materials, access to construction sites, and temporary access around the culverts.

Siltation will be removed from the downstream side of the existing 24-inch diameter culvert beneath the dirt road extension of Pilgrim Road, and a one-way flap gate will be fitted to the downstream side of the culvert. This culvert is shown on Figure 2.

The 600-foot long man-made channel upstream of the Scusset Beach Road culvert will be widened and deepened, with the construction sequenced to minimize exposed excavation. Short lengths of channel will be excavated and then protected with bedding and riprap before additional lengths of channel are excavated. Work in that location will not impact the usage of Scusset Beach State Park or the official or recreational use of the Canal Service Road. Riprap will be placed on the channel side slopes below elevation 5.0 feet NGVD, and the slope above that elevation will be topsoiled and seeded.

The upland portion of the temporary bypass roads will be constructed, and then the temporary channel crossing. Approximately 1 foot of silt which overlies the riprapped channel bottom will be removed from the 210 foot long man-made channel between the Canal Service Road and Scusset Beach Road. Either a 48-inch CMP temporary culvert will be placed in the channel to maintain tidal flows during construction, or a 24-inch CMP temporary culvert will be placed at a higher elevation to allow freshwater drainage from the marsh during construction. Fill will be placed in the channel over the temporary culvert to provide temporary access over the channel during construction.

Construction at the Canal Service Road culvert will be scheduled to minimize impacts on the usage of Scusset Beach State Park and the official and recreational use of the Canal Service Road. Canal Service Road traffic will be routed over the temporary road. Either a 48-inch CMP temporary culvert will be placed in the channel to maintain tidal flows during construction, or a 24-inch CMP temporary culvert will be placed at a higher elevation to allow freshwater drainage from the marsh during construction. Temporary sheeting will be driven and braced around the location of the Canal Service Road culvert to facilitate construction. Work will then proceed with excavation, placement of bedding, and installation of culverts, headwalls, wingwalls, riprap, stop logs and sluice gates. The excavation will be dewatered using pumps. The Canal Service Road will be reconstructed, and Service Road traffic will be returned to the Canal Service Road. It is estimated that installation of the Canal Service Road culvert and gates will take about six weeks.

Construction will then proceed at the Scusset Beach Road culvert, with traffic routed over the temporary road. Existing utilities that run the length of Scusset Beach Road will be relocated over the temporary access road during construction of the Scusset Beach Road culvert. Either a 48-inch CMP temporary culvert will be placed in the channel to maintain tidal flows during construction, or a 24-inch CMP temporary culvert will be placed at a higher elevation to allow freshwater drainage from the marsh during construction. Temporary sheeting will be driven and braced around the location of the Canal Service Road culvert to facilitate construction. Work will then proceed with excavation, placement of bedding, and installation of culverts, wingwalls, and riprap. The excavation will be dewatered using pumps. Scusset Beach Road will be reconstructed, and traffic will be returned to Scusset Beach Road. It is estimated that installation of the Scusset Beach Road culvert will take about four weeks.

The temporary road will then be removed, and the channel between the roads will be widened and deepened. Construction will be sequenced to minimize exposed excavation. Riprap will be placed on the channel side slopes below elevation 5.0 feet NGVD, and the slope above that elevation will be topsoiled and seeded.

The areas which were cleared for the temporary road, staging area, and stockpile area will be revegetated as required.

9.3 OPERATION AND MAINTENANCE

Operation and maintenance will be the responsibility of the Commonwealth of Massachusetts as the non-Federal sponsor, as agreed to in the Project Cooperation Agreement. The Corps will provide the non-Federal sponsor with an Operation and Maintenance Manual outlining specific tasks to be performed. These tasks are described below.

9.3.1 Operation

It is anticipated that the electric sluice gates will be left fully open under non-storm conditions. Initially, tide levels in the marsh resulting from the gates being fully opened will be checked, as discussed in Section 9.6 - "Monitoring Plan", to ensure that the tide levels do not exceed those estimated by the hydraulic model.

The operating rule for the electric sluice gates will require that the gates be closed completely when the tide level in the Cape Cod Canal exceeds the 1-year storm tide level of elevation 6.9 feet NGVD. The electric sluice gates will be wired to allow operation at the site and remotely. The gates could be closed prior to the tide level in the Canal reaching that elevation if a storm is forecast. That method of operation would maximize the area of marsh available for storage of freshwater runoff resulting from any rainfall associated with the storm. The Commonwealth of Massachusetts, as the non-Federal sponsor, would be responsible for monitoring tide levels in the Canal and weather conditions. It is estimated that sluice gates will have to be closed and opened for storms a maximum of approximately five times per year.

Table 11 shows storm water levels in the marsh under existing conditions (with no flow control) and with the recommended plan operated as described above.

Table 11

Comparison of Storm Water Levels in Sagamore Marsh: Existing Culvert With No Provision for Flow Control vs. Recommended Plan With Flow Control

Water Level at Transect 2 (assuming peak runoff is coincident with high tide)

Frequency of Tide Level in Canal	1-year runoff		10-year runoff		50-year runoff		100-year runoff	
	Existing culvert FT NGVD	6'Hx12'W culvert FT NGVD	Existing culvert FT NGVD	6'Hx12'W culvert FT NGVD	Existing culvert FT NGVD	6'Hx12'W culvert FT NGVD	Existing culvert FT NGVD	6'Hx12'W culvert FT NGVD
1-year storm	3.2	3.7	3.3	3.8	3.7	4.2	3.8	4.3
10-year storm	3.5	3.7	3.6	3.8	4.0	4.2	4.1	4.3
50-year storm	3.6	3.7	3.7	3.8	4.1	4.2	4.2	4.3
100-year storm	3.6	3.7	3.7	3.8	4.1	4.2	4.2	4.3

Table 11 shows that storm water levels in the marsh will increase 0.1 to 0.5 feet over existing conditions when operated according to the operating rule. If the gates are closed in response to a forecasted storm prior to the water level in the Cape Cod Canal reaching the 1-year storm tide level, the resulting storm water levels in the marsh will be lower. The Corps will coordinate with the non-federal sponsor and representatives of the Towns of Bourne and Sandwich during the development of plans and specifications to establish procedures to be followed in the event of a natural catastrophe.

9.3.2 Maintenance

The sluice gates, stop log frames, and culverts will be inspected approximately quarterly. During quarterly inspections, the sluice gates will be inspected to ensure that all parts are freely moving and that the gates continue to open and close, the stop log frames will be inspected for integrity, and any large debris will be cleared from the culverts and gate areas.

It is anticipated that marine organisms will accumulate on the sluice gates, stop log frames, and culvert pipes, but not to a level which will impact the project. The service life of the sluice gates and stop log frames is estimated to be 50 years, and the service life of the culverts is estimated to be greater than 50 years.

9.4 IMPACT OF RECOMMENDED PLAN ON PROPERTIES

9.4.1 General

The recommended plan is expected to restore approximately 50 acres of the approximately 186 acres of degraded saltmarsh. As shown in Figure 9, the area of expected saltmarsh restoration is limited to the southern and central portions of the marsh immediately adjacent to the tidal creeks. The northern and perimeter portions of the marsh are not expected to be affected by restoration.

As shown in Table 4, under existing non-storm conditions, water levels in the marsh for astronomic tidal frequencies of eight times per month, two times per month, and once per year are at elevation 2.9 feet NGVD, 3.0 feet NGVD, and 3.0 feet NGVD, respectively. With the recommended plan, water levels in the marsh for astronomic tidal frequencies of eight times per month, two times per month, and once per year will be at elevation 3.2 feet NGVD, 3.3 feet NGVD, and 3.4 feet NGVD, respectively. Therefore, water levels in the marsh will increase 0.3 feet (about 3-1/2 inches), 0.3 feet, and 0.4 feet (about 5 inches) for those astronomic tidal frequencies.

As shown in Table 11, under existing storm conditions, the water level in the marsh for the one year storm tide level combined with the one year runoff is elevation 3.2 feet NGVD. With the recommended plan, the water level in the marsh for the same condition will be elevation 3.7 feet NGVD, or an increase of 0.5 feet (6 inches). More severe storms will be infrequent and of short duration, and in all cases will result in an increase over existing storm water levels of less than 0.5 feet. For the most severe storm analyzed, the one-hundred year storm tide level combined with the one-hundred year rainfall, the existing storm water level in the marsh would be elevation 4.2 feet NGVD, and the storm water level with the recommended plan would be elevation 4.3 feet NGVD. The benefit of being able to close gates with the recommended plan to exclude extreme tide levels is apparent.

Most areas below elevation 6.0 feet NGVD in Sagamore Marsh are either shrub/forested swamp, *Phragmites*, or saltmarsh. The shrub/forested swamp exists around the perimeter of the marsh, and is supported by seeps, springs, and runoff. It is expected that restoration will convert some areas of *Phragmites* into saltmarsh, and convert some areas of shrub/forested swamp into *Phragmites*. Restoration is not expected to convert any areas of non-wetland into wetland, since the proposed water level elevations are much lower than the elevations of existing wetlands.

9.4.2 Developed Parcels

As stated above, astronomic water levels in the marsh are expected to reach elevation 3.2 feet NGVD approximately eight times per month. Areas adjacent to the tidal channels and below that elevation are expected to be restored from *Phragmites* to saltmarsh. No developed parcels are below that elevation.

Storm water levels in the marsh are expected to reach elevation 3.7 feet NGVD for the one year storm tide level combined with the one year runoff. Areas adjacent to the tidal channels and below that elevation are expected to experience infrequent, short-term flooding. Only one house on Phillips Road (244 Phillips Road, Sandwich Map 96 Parcel 67) had a low point in the rear yard below elevation 3.7 feet NGVD, but the low point was beyond the property line. Houses on the west side of the marsh were not surveyed because they are on high ground, but the topographic mapping shows that a small portion of one parcel (5 Vineyard Circle, Bourne Map 7.4 Parcel 21) at the rear of the property may be below elevation 3.7 feet NGVD, although it appears that all land below elevation 6.0 feet NGVD is wetland. The location of wetlands and elevation 3.7 feet NGVD will be surveyed on the two parcels during the development of plans and specifications to determine if either parcel will be impacted by restoration. There were no other houses or yards below elevation 3.7 feet NGVD.

More severe storms will be infrequent and of short duration. For the most severe storm analyzed, the one-hundred year storm tide level combined with the one-hundred year rainfall, the storm water level with the recommended plan would be elevation 4.3 feet NGVD. Besides the two yards cited above, there were no other houses or yards below elevation 4.3 feet NGVD.

9.4.3 Undeveloped Parcels

There are 51 undeveloped parcels of land within and adjacent to Sagamore Marsh. The parcels are listed by ownership in Appendix H. Ownership of undeveloped parcels within and adjacent to Sagamore Marsh is shown on Figure 10. All of the land expected to be affected is existing wetland. No lands which are currently non-wetland are expected to be changed to wetland by this project.

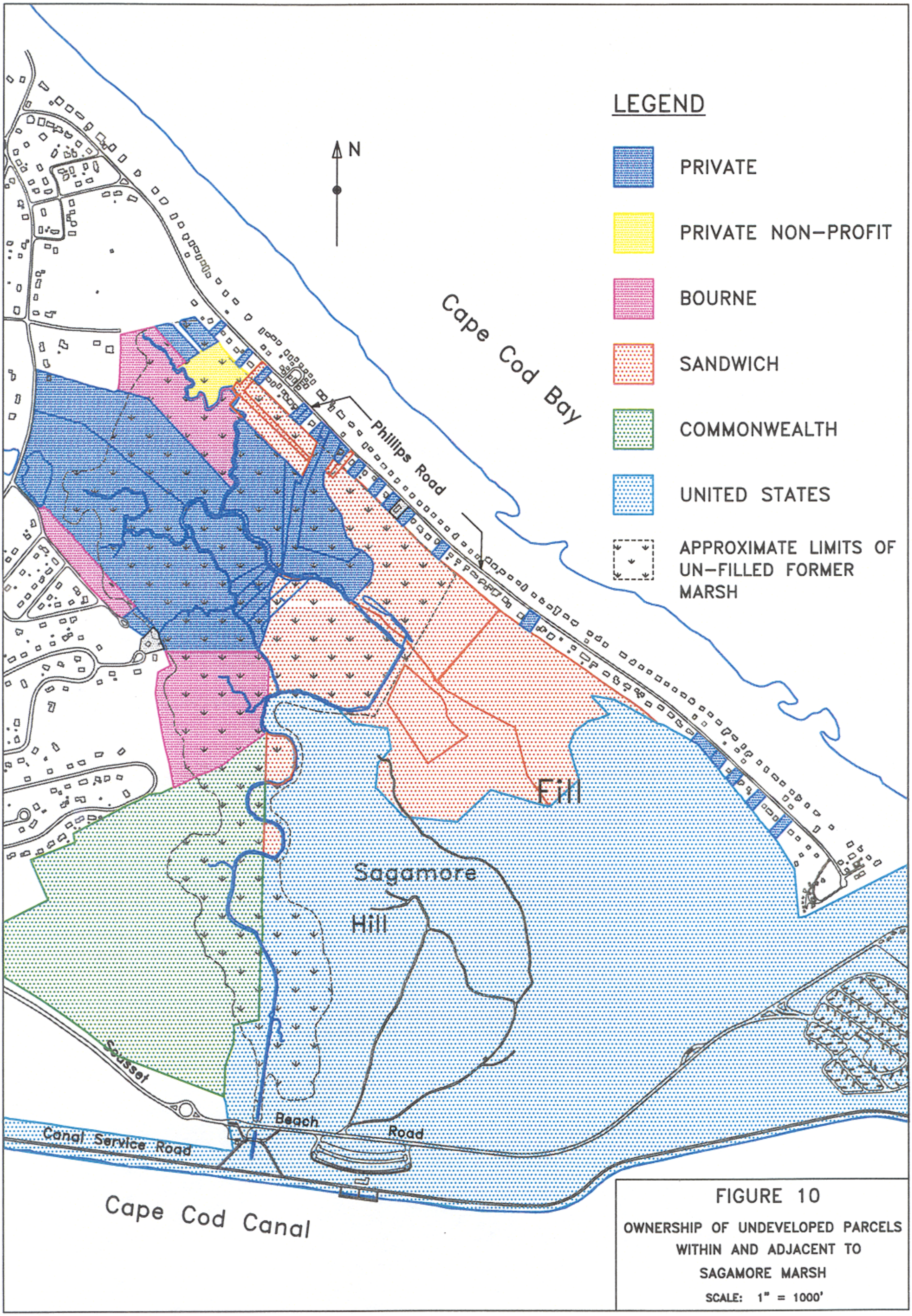


FIGURE 10
OWNERSHIP OF UNDEVELOPED PARCELS WITHIN AND ADJACENT TO SAGAMORE MARSH
SCALE: 1" = 1000'

9.5 REAL ESTATE REQUIREMENTS

The complete report of real estate requirements is contained in Appendix H. A temporary construction easement area of 9.7 acres will be required for construction of the proposed project modifications, for temporary relocation of Scusset Beach Road and the Canal Service Road around the proposed construction, and for staging and stockpile areas. The temporary construction easement area was conservatively sized, and it is expected that it will be reduced in size during the development of plans and specifications. Construction is expected to be completed in nine months, but the temporary construction easement will be acquired for one year to allow for stoppage of work during winter. There are three parcels of land affected by the temporary construction easement, as shown in Appendix H. The parcels are owned by the United States of America, the Commonwealth of Massachusetts, and the Town of Bourne. All land required for the temporary construction easement is non-wetland. There is not expected to be any cost associated with temporary construction easements, since the land is owned by local, State, and Federal Governments.

All lands within and adjacent to the marsh which are expected to be affected by increased tide levels resulting from restoration are existing wetlands. Existing wetlands which are expected to be changed from fresh water wetlands to brackish water wetlands or saltmarsh will not be acquired, since there is no impact to the owner's use or the development potential of the parcel.

It appears that no developed parcels of land will be affected by the one year storm water elevation of 3.7 feet NGVD. All land expected to be affected on undeveloped parcels is existing wetland. No lands which are currently non-wetland are expected to be changed to wetland by this project. Prior to the development of plans and specifications, at the request of owners of undeveloped parcels listed in Appendix H, and with the consent of abutting property owners, the Commonwealth shall arrange for the delineation of wetland areas on the undeveloped parcels. The parcels will be surveyed to determine the location of the wetland line in relation to elevation 3.7 feet NGVD. If it is found that non-wetland areas lie below elevation 3.7 feet NGVD, then either: 1) the project operation will be modified to eliminate that impact, 2) other remedial action will be taken to prevent the impact, or 3) a real estate interest will be acquired by the non-Federal sponsor over the non-wetland portion of the parcel below elevation 3.7 feet NGVD.

9.6 MONITORING PLAN

A monitoring plan has been developed to provide a means to measure the effects that increased tidal inflows from the Cape Cod Canal into Sagamore Marsh will have on surface water levels within the marsh, ground water levels within and adjacent to the marsh, the salinity of a water supply well owned by the North Sagamore Water District north of the marsh, vegetation within the marsh, and the Four-toed salamander population found adjacent to the south end of the project site. The complete Monitoring Plan is presented in Appendix F.

Baseline data is proposed to be gathered during the six-month plans and specifications phase and the nine-month construction phase of the project, and additional data is proposed to be collected during the one- to five-year monitoring period following construction. A one year monitoring period is proposed for surface water levels since those changes will occur immediately after construction. A five year period is proposed to monitor groundwater levels, salinity in the Beach Well, and changes in vegetation.

9.7 ESTIMATED COST

The estimated first cost for the recommended plan is $1,522,000, of which the Federal cost share would be $1,141,500 and the non-Federal cost share would be $380,500. The first cost is broken down as follows: feasibility study, $345,000; planning, engineering and design, $227,000; construction, including contingencies, $776,000; construction management, $89,000; operation and maintenance manual, $10,000; and post-construction monitoring, $75,000. The complete construction cost estimate is contained in Appendix G at November 1995 price levels, with price escalation to September 1996. There is not expected to be any cost associated with temporary construction easements, since the land is owned by local, State, and Federal Governments. It is assumed at this time that there will not be any permanent easements required. Operation and maintenance costs are estimated to be $5,000 per year for the life of the project, based on operation of the electric sluice gates a maximum of approximately five times per year, quarterly inspections of the culverts and gates, and semi-annual clearing of debris.

9.8 CONTINGENCY PLAN

All analyses performed for this study demonstrated that construction of the recommended plan will not cause flooding of adjacent yards, will not impact the performance of existing adjacent septic systems, and will not impact the salinity of the North Sagamore Water District Beach Well. The monitoring plan was established in part to ensure that the project does not impact those resources. If it is found through project monitoring that those resources are being impacted, the amount of water entering the marsh could be reduced by closing the sluice gates as needed. However, based on the groundwater and hydraulic analyses, it is not expected that this will be necessary.

The Army Corps of Engineers and the Executive Office of Environmental Affairs will continue their coordination with the Towns of Bourne and Sandwich and the North Sagamore Water District in order to assess the effects of the project.

SECTION 10

CONCLUSIONS

This report documents the feasibility investigation examining restoration of saltmarsh and estuarine habitat at Sagamore Marsh, located in Bourne and Sandwich, Massachusetts. The study was conducted at the request of the Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA), the non-Federal sponsor. Tidal flushing of Sagamore Marsh was restricted in the mid-1930's when the Cape Cod Canal was widened and deepened, and the marsh has become a predominantly fresh and brackish water system. The purpose of the investigation was to identify the feasibility of restoration of up to approximately 185 acres of former saltmarsh within identified constraints. The constraints were that restoration could not cause flooding of adjacent houses, could not affect the performance of adjacent septic systems, could not impact the salinity of nearby water supply wells, and could not impact navigation in the Canal.

Various alternatives which satisfied the study constraints were examined to determine the recommended plan. The recommended plan consists of: (1) replacing the existing degraded 48-inch diameter reinforced concrete culvert beneath the Canal Service Road and the 48-inch diameter reinforced concrete culvert beneath Scusset Beach Road with 6-foot high by 12-foot wide reinforced concrete box culverts; (2) installing electric sluice gates for primary flow control and stop logs for backup flow control; (3) deepening the man-made channel, which extends 1,100 feet into the marsh from the Canal, to remove siltation and maintain a constant channel slope; and (4) widening the man-made channel from an existing bottom width of 4-feet to a bottom width of 12-feet.

Hydraulic and groundwater analyses determined that the recommended plan will not cause the flooding of adjacent houses, will not affect the performance of adjacent septic systems, will not impact the salinity of nearby water supply wells, and will not impact navigation in the Cape Cod Canal. Project benefits are expected to be the restoration of approximately 50 acres of saltmarsh and estuarine habitat.

SECTION 11

RECOMMENDATIONS

The report recommends that the selected plan be approved for development of plans and specifications and implementation under the Section 1135 authority.

ENVIRONMENTAL ASSESSMENT

Final
Environmental Assessment
and
Clean Water Act
Section 404(b)(1) Evaluation

Sagamore Salt Marsh Restoration
Section 1135, Environmental Restoration Project
and
Coastal America Project
Sandwich, Massachusetts

November 1996

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

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APPENDICES

SECTION I - LOCATION AND AUTHORIZATION

LOCATION

The project site is located at the northern end and west side of the Cape Cod Canal in Sandwich, Massachusetts (Figure 1). The connection with tidal water from the Canal occurs through a 48-inch culvert at the former upstream end of the marsh.

AUTHORIZATION

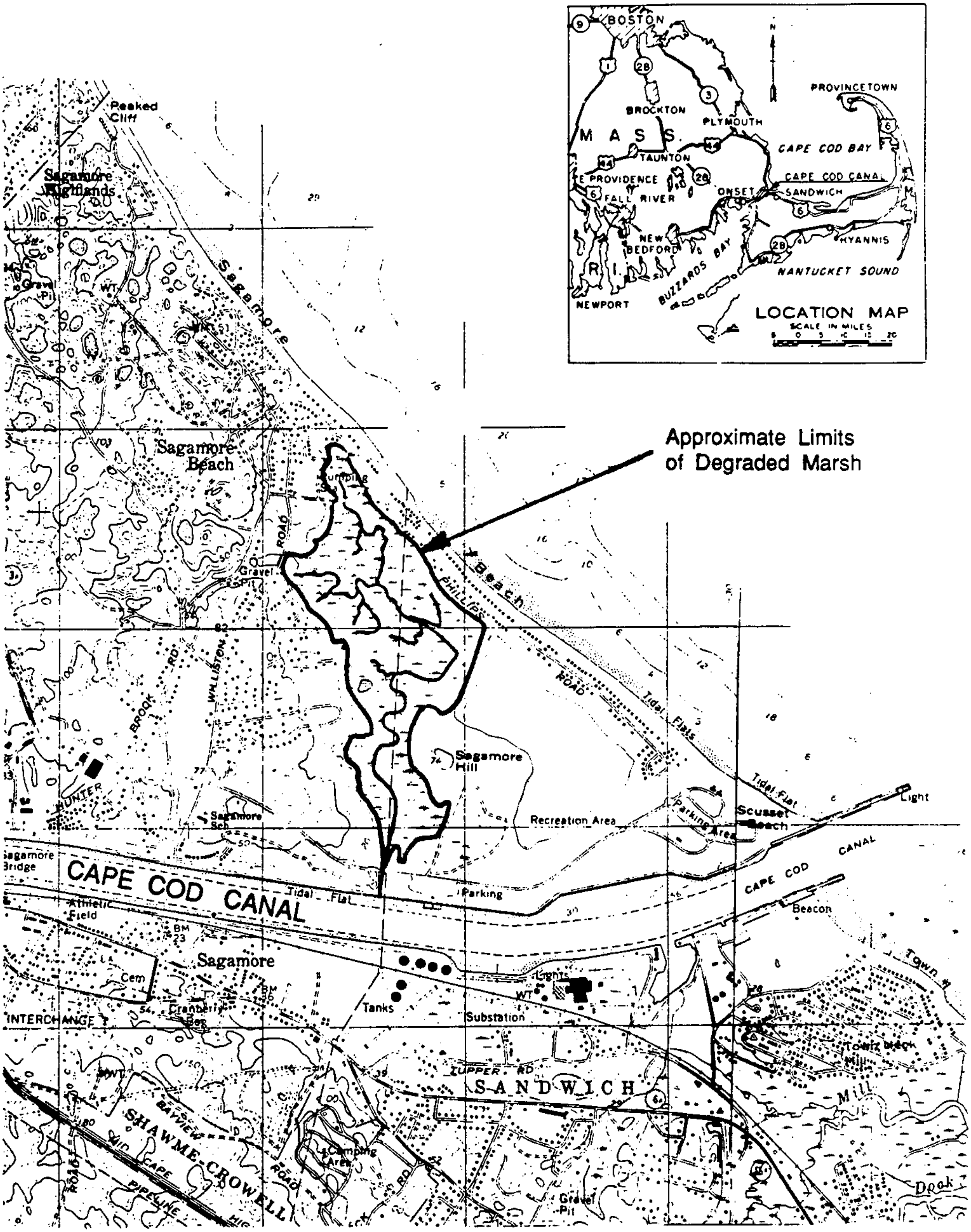
The feasibility investigation for this project examines restoration of the northern portion of the former Sagamore salt marsh (Figure 1) under the authority of Section 1135 of the Water Resources Development Act of 1986 (PL 99-662), as amended. This document has been prepared in compliance with the National Environmental Policy Act (NEPA) and documents compliance with all applicable Federal environmental laws and regulations.

SECTION II - PURPOSE AND NEED FOR THE ACTION

The purpose of this project is to restore estuarine habitat, salt marsh and associated values to fish and wildlife. The majority of the Sagamore Marsh consists of degraded freshwater/brackish habitat due to reduced tidal range. The limited tidal range does not allow most of the system to support the estuarine species that previously existed at the site. The need for salt marsh restoration has been identified as a high priority by the national and regional Coastal America implementation partnerships.

The former Sagamore salt marsh measured approximately 360 acres. Disposal of excavated and dredged material during construction of the Canal resulted in filling of approximately 175 acres at the southern end of the marsh. The disposal along with the accretion of littoral material north of the Canal jetties, resulted in closing of the tidal inlet from Cape Cod Bay into Sagamore Marsh. Restoration of the filled portion of the marsh, which is separated from the project focus area by a dike, is beyond the scope of this project. This project focuses on the 185 acre area north of the dike up to the existing inlet on the Canal. Approximately 50 percent of the existing wetland north of the dike is dominated by common reed (*Phragmites australis*).

Common reed has relatively low value for fish and wildlife. It also presents a potential fire hazard, makes management of mosquitoes difficult, and has a lower aesthetic value than the natural salt marsh. Periodic tidal flushing of the marsh with salt water will restore estuarine habitat and maintain soil water salinity levels high enough to discourage the growth of common reed.



Sagamore Marsh Restoration

FIGURE 1

SECTION III - PROPOSED PLAN

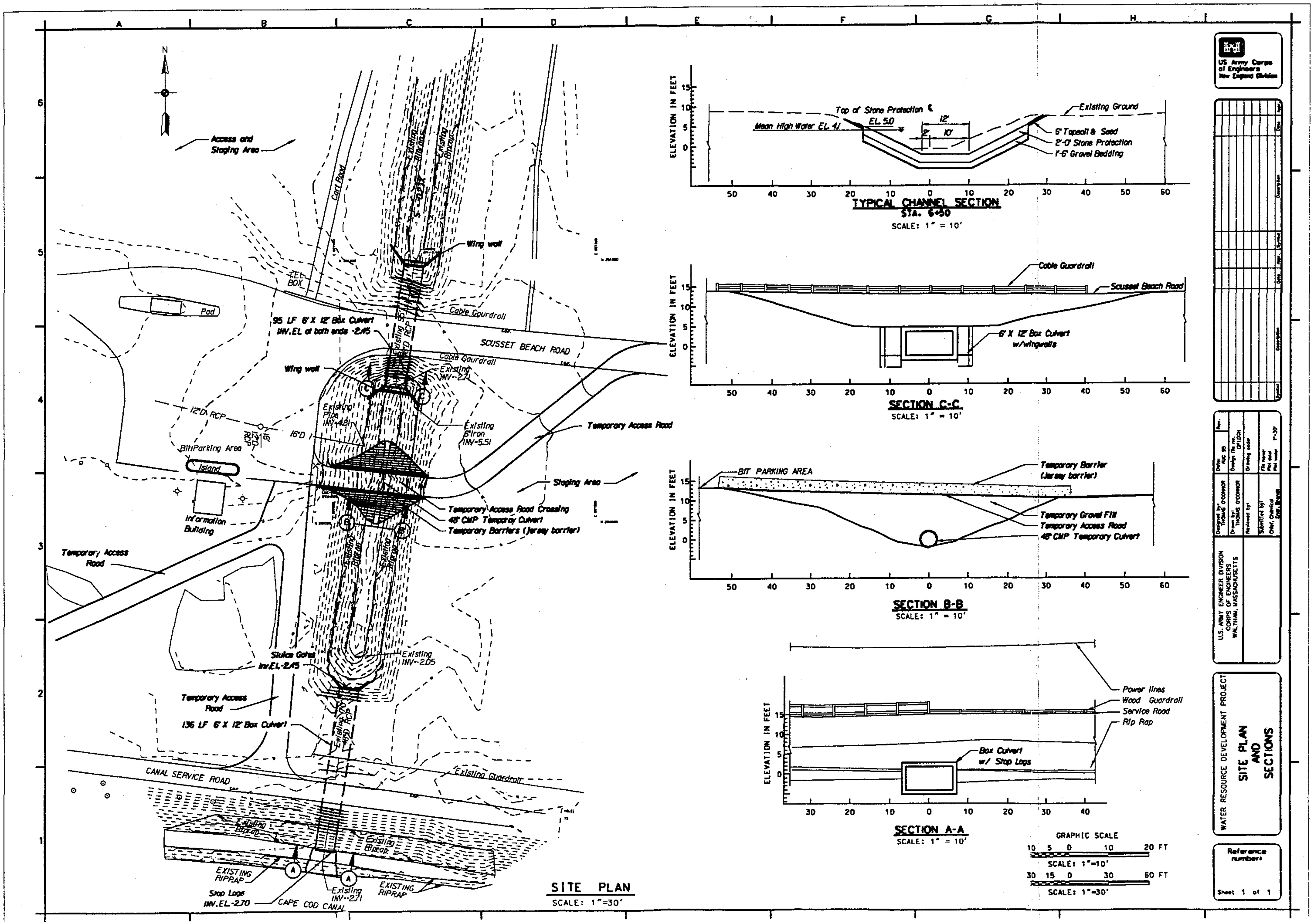
The recommended alternative for this project is described in detail in Section 9 of the feasibility report. In general, the proposed plan involves the installation of culverts through Scusset Beach Road and the Canal service road, or bike path, and increasing the size of the existing outlet channel (Figure 2).

The new culverts will consist of three 6-feet high by 4-feet wide culverts under each outlet crossing. The set of culverts beneath the bike path will be equipped with electric sluice gates and a stop log backup system to control the level of tidal water during coastal flooding events.

The existing 1,300 foot riprap channel will be deepened and widened to improve hydraulic conveyance capacity. The culverts beneath the Canal service road will be placed at the same elevation and slope as the existing culvert. That is, the invert on the Canal-side will be at elevation -2.7 feet NGVD, and the invert on the marsh-side will be at elevation -2.45 feet NGVD. The culverts beneath Scusset Beach Road will be placed at elevation -2.45 feet NGVD. Between the Canal service road and Scusset Beach Road, siltation will be removed to deepen the channel from an existing invert elevation of -1 ft NGVD to -2.45 feet NGVD. On the marsh-side of the Scusset Beach Road culverts, the channel will slope from an invert elevation of -2.45 feet NGVD upward at 0.23 percent to the upstream end of the riprap to meet the existing upstream invert elevation. The bottom width will be increased from approximately 4 feet to 12 feet by excavating and moving the east bank of the channel 8 ft toward the east and replacing the 2:1 side slope. Stone protection will be replaced up to elevation 5 feet NGVD on the east bank. The remainder of this bank up to existing grade will be topsoiled and hydroseeded with an erosion control mixture containing switchgrass (<u>Panicum virgatum</u>).

Two upland staging areas will be established. One will abut the east side of the downstream channel segment and the south side of Scusset Beach Road. The second will be located on the west side of the riprap channel above Scusset Beach Road. A thirty-foot wide work area will be cleared of vegetation along the west side of the riprap channel bank above Scusset Beach Road and along the east side of the channel between the bike path and Scusset Beach Road.

Construction will take place during the 9-month period between August 1 and May 1 with the culvert and channel work occurring after October 1. A temporary road will be constructed across the channel to allow continued access to areas east of the construction area. To maintain tidal flow and freshwater outflow during the construction period, a temporary 48-inch corrugated metal pipe (CMP) will be placed in the channel under the



US Army Corps of Engineers New England Division
Access and Staging Area
Cart Road
Existing Riprap
Wing wall
ELEC. BOX
Pad
Cable Guardrail
95 LF 6' X 12' Box Culvert INV.EL at both ends -2.45
SCUSSET BEACH ROAD
Wing wall
Existing INV-2.71
12"D RCP
16"D
Existing Pipe INV-4.81
Existing 6"Iron INV-5.51
Temporary Access Road
Bit Parking Area
Island
Staging Area
Information Building
Temporary Access Road Crossing
48" CMP Temporary Culvert
Temporary Barriers (Jersey barrier)
Temporary Access Road
Sluice Gates INV.EL-2.45
Existing INV-2.05
Temporary Access Road
136 LF 6' X 12' Box Culvert
CANAL SERVICE ROAD
Existing Guardrail
Existing Riprap
EXISTING RIPRAP
Stop Logs INV.EL-2.70
CAPE COD CANAL
Existing INV-2.71
EXISTING RIPRAP
SITE PLAN
SCALE: 1"=30'
ELEVATION IN FEET
Top of Stone Protection
EL 5.0
Mean High Water EL 4.1
Existing Ground
12'
2' 10'
6" Topsoil & Seed
2'-0" Stone Protection
1'-6" Gravel Bedding
TYPICAL CHANNEL SECTION
STA. 6+50
SCALE: 1" = 10'
Cable Guardrail
Scusset Beach Road
6' X 12' Box Culvert w/wingwalls
SECTION C-C
SCALE: 1" = 10'
BIT PARKING AREA
Temporary Barrier (Jersey barrier)
Temporary Gravel Fill
Temporary Access Road
48" CMP Temporary Culvert
SECTION B-B
SCALE: 1" = 10'
Power lines
Wood Guardrail
Service Road
Rip Rap
Box Culvert w/ Stop Logs
SECTION A-A
SCALE: 1" = 10'
GRAPHIC SCALE
SCALE: 1"=10'
SCALE: 1"=30'
U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS WALTHAM, MASSACHUSETTS
WATER RESOURCE DEVELOPMENT PROJECT
SITE PLAN AND SECTIONS
Reference numbers
Sheet 1 of 1

FIGURE 2

temporary road between the two existing culverts. Flow will be conducted around each of the existing culverts during excavation and replacement by installing metal sheeting. The channel will be constructed in segments to minimize exposure of disturbed earth to tidal flow. Segments will be excavated, then stabilized with riprap before following segments are excavated.

The following general sequence will be followed: 1) Install erosion controls and clear staging areas; 2) construct upstream channel segment; 3) install bypass CMP and roadway; 4) install bike path culvert and gates; 5) install Scusset Beach Road culvert; 6) construct downstream channel segment.

The stone from the existing riprap will be reused on-site. Excavated material that can not be reused for construction will be disposed of at the town landfill or in a suitable offsite upland location.

Mosquito control will be implemented as needed by the local sponsor to ensure that the restoration of tidal flow does not increase mosquito populations.

SECTION IV - ALTERNATIVES CONSIDERED

ALTERNATVE 1 NO ACTION ALTERNATIVE

If no action is taken to restore the salt marsh, it will continue to exist in its present degraded condition. The site may change to a shrub, then forested freshwater wetland over the long term, but the persistence of common reed suggests that this process would be slow, particularly if fires continue to occur in the marsh. The significant improvements in fish and wildlife resource value that would accrue with the project would not be achieved.

ALTERNATIVE 2 CULVERT, SLUICE GATES, AND CHANNEL AT THE CAPE COD CANAL

This alterative consists of a combination of culverts, gates, and channel improvements in the location of the existing connection to tidal flow at the Cape Cod Canal. A large number of size options were considered to develop a recommended culvert and channel size. The options were compared through an Incremental Analysis presented in Appendix C of the feasibility report. The recommended alternative presented in Section III was selected from among these options. Under this alternative, all culvert sizes would be equipped with electric sluice gates to maintain tide levels within prescribed limits to avoid flooding of surrounding uplands. A backup stop log system would also be installed to further reduce the potential for upland flooding in case of failure of the primary system.

ALTERNATIVE 3 CULVERTS, AUTOMATIC TIDE GATES, AND CHANNEL AT THE CAPE COD CANAL

This alterative consists of the same combinations of culverts and channel improvements as described for Alternative 2 and evaluated in Appendix C. With this alternative, all culvert size options would be equipped with automatic tide gates to maintain tide levels within prescribed limits to avoid flooding of surrounding uplands. A backup system (e.g., sluice gates or stop logs) that can be closed manually would also be installed to further reduce the potential for upland flooding during storm events.

ALTERNATIVE 4 SCUSSET BEACH CHANNEL

The connection of the Sagamore Marsh to tidal flow historically occurred via a channel through Scusset Beach near the existing entrance to the Canal. An obvious alternative to restore the marsh would be to restore this former tidal connection. This alternative would involve reconstruction of a channel in the location of the historic channel through Scusset Beach (Figure 3). The channel would have to travel through about 4,000 feet of filled wetland to reach the nearest existing channel that would restore tidal flow to the northern portion of the marsh. Because the elevation of this area has been increased through dredged material disposal, very little overbank flow would occur over this length. More significantly, the channel would have to be maintained by jetties and possibly a sediment control system. For these reasons, this alternative was beyond the scope of the existing study and was eliminated from detailed study.

SECTION V - AFFECTED ENVIRONMENT

GENERAL

The Sagamore Marsh project area includes the area bounded by the Cape Cod Canal (the Canal) and Sagamore Hill and the dike for the dredged material disposal area to the south, residential properties on Scusset Beach to the east, and residential properties on the north and west. Much of this area has changed from salt marsh and estuarine habitat to dominance by common reed (<u>Phragmites</u> <u>australis</u>; hereafter referred to as Phragmites) and shrub vegetation since the disposal of dredged material and the construction of the Canal. This degradation of the vegetation type has been observed at other sites in New England where a similar reduction in tidal exchange has occurred. The vegetation type reflects degraded estuarine conditions.

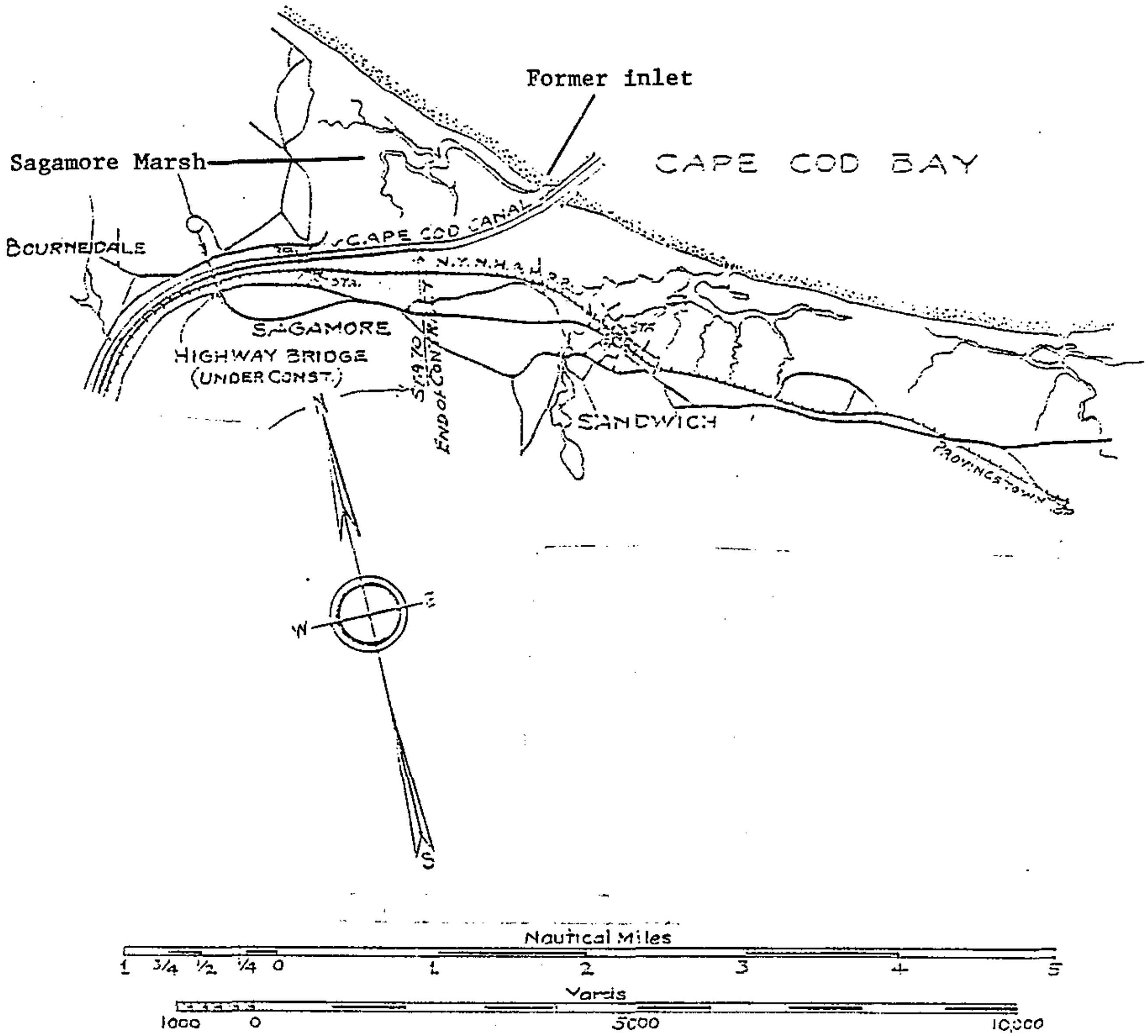


Figure 3. Former Inlet Location

WETLANDS, VEGETATION, AND COVER TYPES

Cover types at the Sagamore Marsh study site consist of five major types: fresh and estuarine open water, salt marsh, common reed marsh, shrub and forested swamp, and upland habitats. The approximate area of each vegetation community is shown in Table 1. These cover types are described in the following paragraphs and are shown on Figure 4. Figure 4 was prepared using 1994 color aerial photography with an approximate scale of 1-inch = 600 feet.

Cover Types

General. Vegetation types in a coastal wetland are strongly influenced by salinity. Existing salinity levels in the channel are quite high well upstream in the marsh. The salinity was measured at 23 parts per thousand (ppt) during a spring high tide on October 5, 1994 at the channel confluence shown on Figure 5. The high salinity levels in the creek and presence of salt marsh species on the creek banks well into the interior of the marsh indicate that the vegetation community reflects the reduced tide range rather than reduced soil water salinity due to freshwater inflow. Levees (resulting from natural sediment deposition or disposal of dredged material) along the creekbanks confine the creek flow and apparently do not allow widespread flooding of the marsh surface. Where the levees are not present, areas of salt marsh and stunted Phragmites exist outside the creekbanks.

Salt Marsh. Salt marsh makes up about 9.3 acres of the Sagamore Marsh. Salt marshes are generally classified into two types (high marsh and low marsh) based on the dominant vegetation and its characteristics and the frequency of tidal flooding. The low salt marsh vegetation consists almost exclusively of salt marsh cordgrass (Spartina alterniflora). The taller form of this species grows in the low marsh where frequent flooding and draining of the sediments creates favorable growth conditions. The low salt marsh extends from a lower limit around mean sea level, depending on a number of hydrologic factors, to about mean high water (MHW). (Although there is some discussion about the accuracy of using MHW as the upper limit in the literature (Nixon, 1982; Lefor et. al., 1987; McKee and Patrick, 1988), within the tide range occurring at the Sagamore Marsh, MHW is a reasonable estimate.) Small amounts of low marsh line the main channel at the Sagamore marsh. Salt marsh cordgrass borders both sides of the riprap entrance channel with an approximate width of one meter. These areas are too small to show on Figure 4. Tall salt marsh cordgass is also present along the channel up to 4,400 feet upstream (straight line distance) of the culvert at Scusset Beach Road.

The high salt marsh is situated between about MHW and the level of the highest astronomic tides (Lefor et. al., 1987;

TABLE 1.
VEGETATION TYPES AT THE SAGAMORE MARSH

Cover Type	**Acres**
Tidal creeks	2.3
Permanent ponds	1.3
Pannes	0.1
Short salt marsh cordgrass marsh	2.8
Other salt marsh	6.5
Stunted common reed marsh	15.5
Tall common reed marsh	71.7
Mixed common reed and shrubs	9.0
Freshwater emergent wetland	0.6
Shrub swamp	63.3
Forested swamp	15.4
Total	188.5

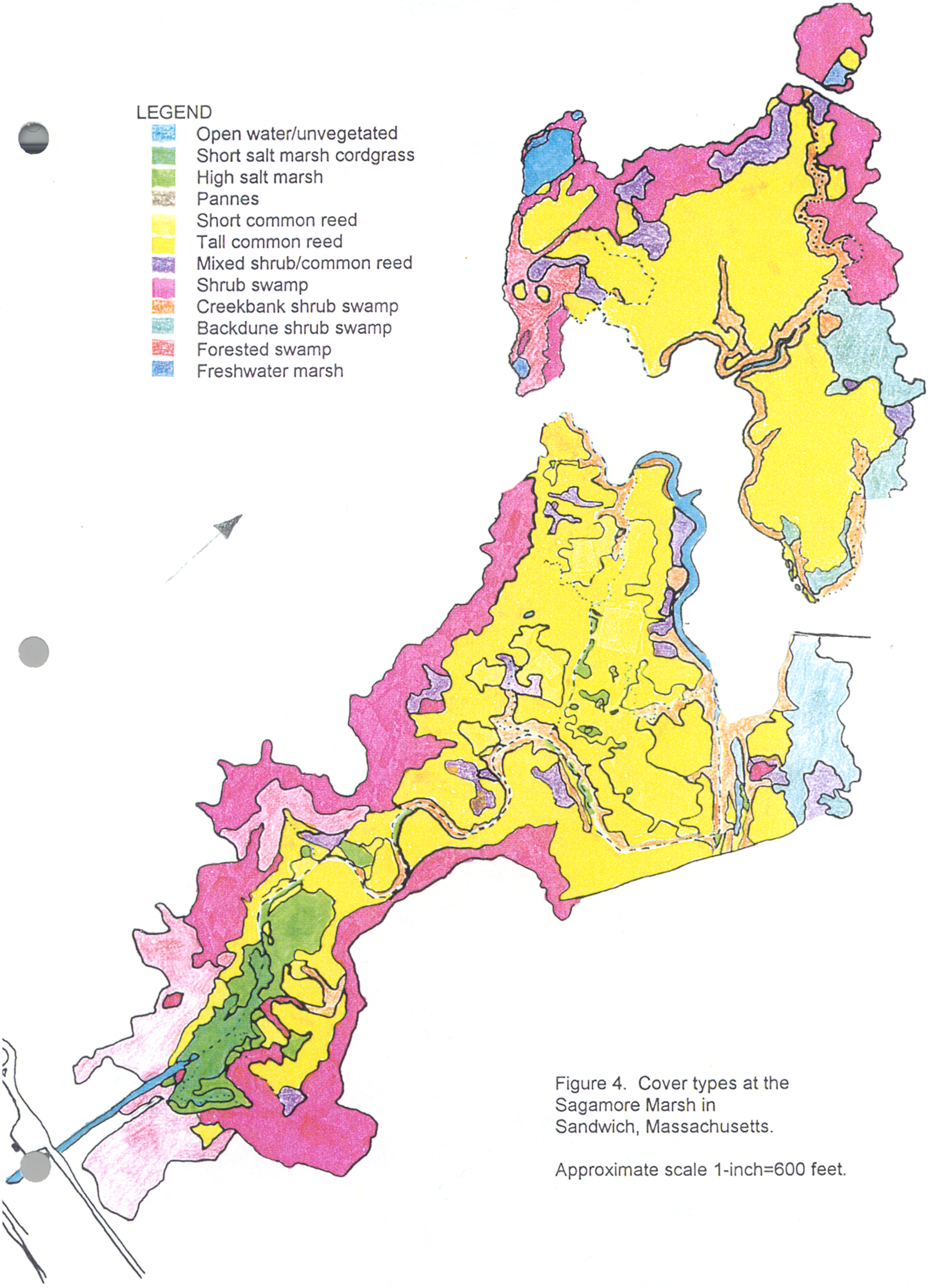


Figure 4. Cover types at the Sagamore Marsh in Sandwich, Massachusetts.

Approximate scale 1-inch=600 feet.

Bertness and Ellison, 1987) or mean spring high water (MSHW) (Niering and Warren, 1980). MSHW is probably a good estimate of the upper limit of the marsh plain with higher astronomic tides and storm tides flooding the generally steeper sloped upper border of the marsh where high tide bush (Iva frutescens) and switchgrass (Panicum virgatum) occur.

The high marsh supports a greater diversity of vegetation than the low marsh, but is usually dominated by one or a combination of four plants. Salt meadow grass (Spartina patens) is usually most abundant and grows over most of the high marsh. Spike grass (Distichlis spicata) grows intermixed with salt meadow grass and is often dominant in areas of particularly high or low salinity, where the soils are waterlogged, and in recently disturbed areas. Black grass (Juncus gerardi) grows in locally high areas and on the upper border of the high marsh. The short form of salt marsh cordgrass grows where the soil is waterlogged or covered with shallow water.

Most of the existing salt marsh at the Sagamore Marsh is located in the vicinity of the inlet although small areas of salt marsh are present in the interior of the marsh near a major feeder channel. Large areas of the existing salt marsh are dominated by short salt marsh cordgrass which probably reflects poor drainage conditions. Poor drainage may result from either the tidal restriction resulting from the undersized culvert or three stone weirs that are present in the existing channel near the end of the riprap. The remainder of the area classified as salt marsh in Figure 4 is high salt marsh dominated by salt meadow grass. In addition to the dominant salt marsh species listed above, other species observed in these portions of the marsh include common glasswort (Salicornia europaea), sea lavender (Limonium nashii), seaside goldenrod (Solidago sempervirens), high tide bush, switchgrass, sea blight (Suaeda linearis), marsh orach (Atriplex patula), and Phragmites.

Salt marsh cordgass intermittently borders the main channel in fairly large bands (>10 feet in width) up to 4,500 feet (straight line distance) into the marsh. Small amounts of salt marsh vegetation (e.g., salt meadow grass, common glasswort, and marsh orach) are present in a very thin fringe intermixed with Phragmites and other vegetation on the channel banks up to about 400 feet beyond the confluence of the two upstream portions of the main channel.

Intertidal and Subtidal Channel Habitats. The existing inlet to the Sagamore Marsh enters through the Cape Cod Canal. The intertidal areas in the vicinity of the culvert on the Canal, and the culvert itself are covered with varying amounts of barnacles, blue mussels (Mytilus edulis), and periwinkles (Littorina littorina). Blue mussels line the interior of the culvert as well.

The main channel leading into the Sagamore Marsh supports high quality habitat with a strong marine influence. Because of the constricted drainage, a large portion of the channel is subtidal; it is not completely exposed during any low tides. Blue mussel beds cover about one-third of the 67-meter length of the segment of the entrance channel between the Canal and Scusset Beach Road, but the majority of the mussels in the beds were dead during the August 1994 field visit, probably as a result of predation. The mussel beds ranged from about 30-100 percent cover. Dense sea lettuce (Ulva lactuca) also covers portions of this segment of the channel. The remainder of the channel supports unvegetated intertidal and subtidal habitat, apparently underlain by the stone channel protection. Mummichogs (Fundulis sp.), Atlantic silversides (Menidia menidia), and salps (Salpa fusiformis) were observed in this portion of the channel.

The next channel segment consists of the portion upstream of Scusset Beach Road to the end of the stone (riprap) protection. A layer of blue mussels was present on the interior of the culvert outlet upstream of Scusset Beach Road. The stone protection in the channel is suitable substrate for a number of species that may not normally occur in a muddy tidal creek. Small amounts of oysters (Crassostrea virginica) are present in a few areas on the rocky substrate. Rock weed (Fucus visiculosus) is present along much of the edge of the channel in the lower intertidal zone below the salt marsh cordgrass. A mussel bed is present in this area extending from the culvert outlet about 18 meters upstream and ranging in percent cover from about 40-100 percent. Green crabs, periwinkles, and hermit crabs were observed in this area and other parts of the channel. Fine sand overlays the stone protection at the base of the channel limiting the vertical habitat availability for benthic infauna.

Eelgrass (Zostera marina) is abundant in much of the main channel. Eelgrass is a very valuable ecological resource because of its productivity and value as food and cover for aquatic organisms. It first appears in the channel as a small clump about 90 feet upstream of the culvert. The next occurrence of eelgrass is 425 feet upstream of the culvert, but it is not abundant until about 950 feet upstream, after the ripraped portion of the channel ends. Beyond the riprap, tall, dense eelgrass covers much of the channel bottom in apparent waves (i.e., higher density areas - 100% cover - separated by 2-meter breaks with less dense cover) up to approximately 3,300 feet (in a straight line) upstream of the culvert. Sparse eelgrass and some widgeon grass (Ruppia maritima) is present in the channel up to 4,000 feet (in a straight line) from the culvert.

Common Reed (Phragmites australis) wetlands. Phragmites covers the largest area of the Sagamore Marsh. Phragmites is a relatively low value species ecologically compared to salt marsh plant species which are generally recognized as having high ecological value. The tendency of Phragmites to grow in dense stands which exclude other species of vegetation reduces the benefits which accrue to the marsh system with a diversity of vegetation. Although its productivity is quite high, the value of its plant material is limited. Whereas a portion of salt marsh production is exported to the aquatic and terrestrial food webs, Phragmites production is, to a large extent, unavailable to food webs. It has relatively low value as a food item because of the coarseness of its stems and leaves and its hairy seeds. In addition, Phragmites cover is a potential fire hazard and Roman et al. (1984) have described stagnant Phragmites marshes as prime mosquito breeding areas.

Phragmites has been divided into three main community types for the cover map and ecological assessments. Tall Phragmites, shown in yellow, makes up about 72 acres of the wetland and reflects areas of lower salinity and tidal influence. Stunted Phragmites, shown in bright yellow, makes up about 16 acres of the marsh and reflects presumably higher tidal influence and salinity. In these areas of stunted Phragmites, pannes containing the salt marsh species, common glasswort, are interspersed reflecting areas of lower elevation and higher salinity. Marsh orach and goldenrod (Solidago sempirvirens) were observed within the stunted Phragmites areas.

Portions of the wetland contain a mixture of Phragmites and wetland shrub vegetation. These areas, shown in purple on the cover map, reflect conditions transitional between the shrub swamp and Phragmites marsh.

Shrub and Forested Swamp Habitats. There are three main shrub swamp types at the Sagamore wetland. The first, shown in orange on the cover map, occurs mostly on depositional levees along the edge of the main channel. These areas are drier than the channel habitats and the marsh that borders them. The vegetation observed in this cover type is listed in Table 2. There is some overlap between the shrub and forested swamp map units.

Another shrub swamp habitat exists along the backdune behind Scusset Beach. This cover type is shown in dark green on the cover map. This cover type may have occupied a larger portion of the habitat prior to the fire. The vegetation observed in this cover type is listed in Table 3.

The third shrub swamp cover type exists mainly along the upland border on the west side of the marsh. This cover type, shown in pink, contains plant species typical of southeastern Massachusetts shrub swamps. The plant species are listed on Table 4. The forested swamp contains species similar to this shrub swamp habitat and is dominated by red maples. The main difference is the absence or near absence of mature red maple trees in the areas mapped as shrub habitat. The forested swamp is shown in red on the cover map.

Freshwater Emergent Wetland. Small areas dominated by cattails (Typha sp.) are present at the upstream end of the marsh. These areas are shown in dark blue on the cover map.

Adjacent Wetland Habitat. The portion of the Sagamore wetland south of the dike contains a wetland impacted by dredged material disposal. The elevations in this area are higher than elevations north of the dike and the substrate differs from other portions of the marsh. The majority of this area contains shrub/forested swamp with species similar to the swamp along the western side of the marsh and also pitch pine (Pinus rigida) and big toothed aspen (Populus grandidentata). Much of the northern portion is dominated by common reed and the area abutting the houses on Phillips Road supports habitat similar to the back dune shrub swamp previously described.

Surrounding Uplands. The uplands surrounding the Sagamore wetland are typical of upland habitats on Cape Cod. They support a mixed forest with pitch pine and oaks. The vegetation community in the vicinity of the culverts and riprap channel that would be replaced with the project was examined in greater detail. The upland adjacent to the channel supports scrub oak (Quercus ilicifolia), scarlet oak (Q. coccinea), white oak (Q. alba), black cherry, big toothed aspen, red maple, bayberry, arrow wood, poison ivy, Virginia creeper, and upland grasses.

The upland between the Canal embankment and the first culvert outlet and the upper banks of the channel between the Canal and Scusset Beach Road support staghorn sumac (Rhus typhina), bayberry, black cherry, arrow wood, red cedar, grape (Vitus sp.), slough grass (Spartina pectinata), fireweed, goldenrod, and other upland weeds and grasses.

BENTHIC INVERTEBRATES AND SHELLFISH

Benthic Invertebrates

Benthic invertebrates include clams, snails such as periwinkles (e.g., Littorina spp.), crabs (e.g., green crab, Carcinus maenas), polychaete worms (e.g., (Nereis virens), and amphipod crustaceans (e.g., Corophium insidiosum). Benthic organisms play an important role in the estuarine detritus-based food web. Those species that feed on detrital material, produced in large part by the surrounding salt marshes, accelerate decomposition and reuse of organic material as well as providing a food source for animals higher in the food web such as fish and birds (Whitlatch, 1982).

Table 2. Vegetation Composition of the Shrub Wetland Banks.

Arrow wood	Viburnum dentatum
Pussy willow	Salix nigra
Poison ivy	Rhus radicans
Blueberry	Vaccinium corymbosum
Pokeweed	Phytolacca rigida
Woolgrass	Scirpus cyperinus
Goldenrod	Euthamia spp.
Viburnum	Viburnum sp.
Fireweed	Erechtites hieracifolia
Aster	Aster sp.
Smartweed	Polygonum sp.
Common reed	Phragmites australis
Atlantic white cedar (dead)	Chamaecyparis thyoides
Red chokebrry	Pyrus arbutifolia
Bayberry	Myrica pensylvanica
Soft rush	Juncus effusus
Reed-bentgrass	Calamagrostis
Blackberry	Rubus cuneifolius
Massachusetts fern	Thelypteris simulata
Winged sumac	Rhus copallina

Table 3. Plants in the Backdune Shrub Swamp Cover Type

Woolgrass	Scirpus cyperinus
Marsh Saint John's Wort	Hypericum virginicum
Hardhack	Spirea tomentosa
Sedge	Carex sp.
Poison ivy	Rhus radicans
Winterberry	Ilex verticillata
Arrow wood	Viburnum dentatum
Bayberry	Myrica pensylvanica
Pussy willow	Salix nigra
Black cherry	Prunus serotina
Red chokebrry	Pyrus arbutifolia
Red maple	Acer rubrum

Table 4. Plants of the Shrub and Forested Swamp Habitats.

Red maple	*Acer rubrum*
Swamp azalea	*Rhododendron viscosum*
Pussy willow	*Salix discolor*
Gray birch	*Betula populifolia*
Arrow wood	*Viburnum dentatum*
Brier	*Smilax* sp.
Poison ivy	*Rhus radicans*
Meadow sweet	*Spiraea latifolia*
Alder	*Alnus* sp.
Glossy buckthorn	*Rhamnus frangula*
Blueberry	*Vaccinium corymbosum*
Blackberry	*Rubus cuneifolius*
Common reed	*Phragmites australis*
Cinnamon fern	*Osmunda cinnamomea*
Sensitive fern	*Onoclea sensibilis*
Massachusetts Fern	*Thelypteris simulata*
Chain fern	*Woodwardia* sp.
Skunk cabbage	*Symplocarpus foetidus*

Six benthic core samples were collected to characterize the benthic community in the main channel at the Sagamore Marsh (Figure 5). Samples were collected with a core tube with an area of 40.7 cm^2 to a length of up to 20 cm, sieved onsite with a 0.5 mm screen, and returned to the laboratory and preserved in a solution of 10% formalin. The samples were then transported to Sheldon Pratt at the University of Rhode Island, Graduate School of Oceanography, for sorting and identification. Methods and results of these analyses are presented in Appendix EA-B and summarized below.

The channel in the vicinity of samples was dominated by polychaete and oligochaete annelid worms. Other organisms included arthropods, a gastropod, and bivalves.

The channel center had a relatively high diversity of species, including bivalve mollusks, the oligochaetes Pelosolex benedeni and several tubificids, and polychaetes from the families Capitellidae, Orbiniidae, Nereidae, and Spionidae. A small number of juvenile soft shelled clams (Mya arenaria) were collected in Sample 3, but this commercially important species is apparently not an important component of this system.

Intertidal samples in the salt marsh cordgrass marsh had fewer species than the channel samples and contained species adapted to intermittent exposure on the marsh surface. The oligocaete, Lumbricillus lineatis, was the most abundant species in these samples.

A sample from subtidal peat at the end of the riprap channel included species represented in the channel and low marsh samples. *The annelid,* Streblospio benedicti *and a tubificid worm* were most abundant.

FISH

Fish are an important component of the marsh/estuarine system. Sampling of fish was not conducted for this assessment, however, fish use can be characterized by considering general fish use of salt marsh-dominated estuaries in the area. Some important estuarine fish that use salt marshes are listed in Table 5. This list is based on information prepared by Werme (1981) (as presented by Teal, 1986) for the Great Sippewissett Salt Marsh in Massachusetts. Most fish use the marsh portion of the estuarine system when it is temporarily flooded by tides, but some, such as the mummichog (Fundulus heteroclitus) and striped killifish (F. majalis), are permanent residents of the marsh ponds. In general, the more frequently flooded the marsh is the more it is used by non-resident fish. Mummichogs were observed in traps in the Sagamore Marsh channel. Atlantic silversides (Menidia menidia) and American eel (Anguilla rostrata) were also

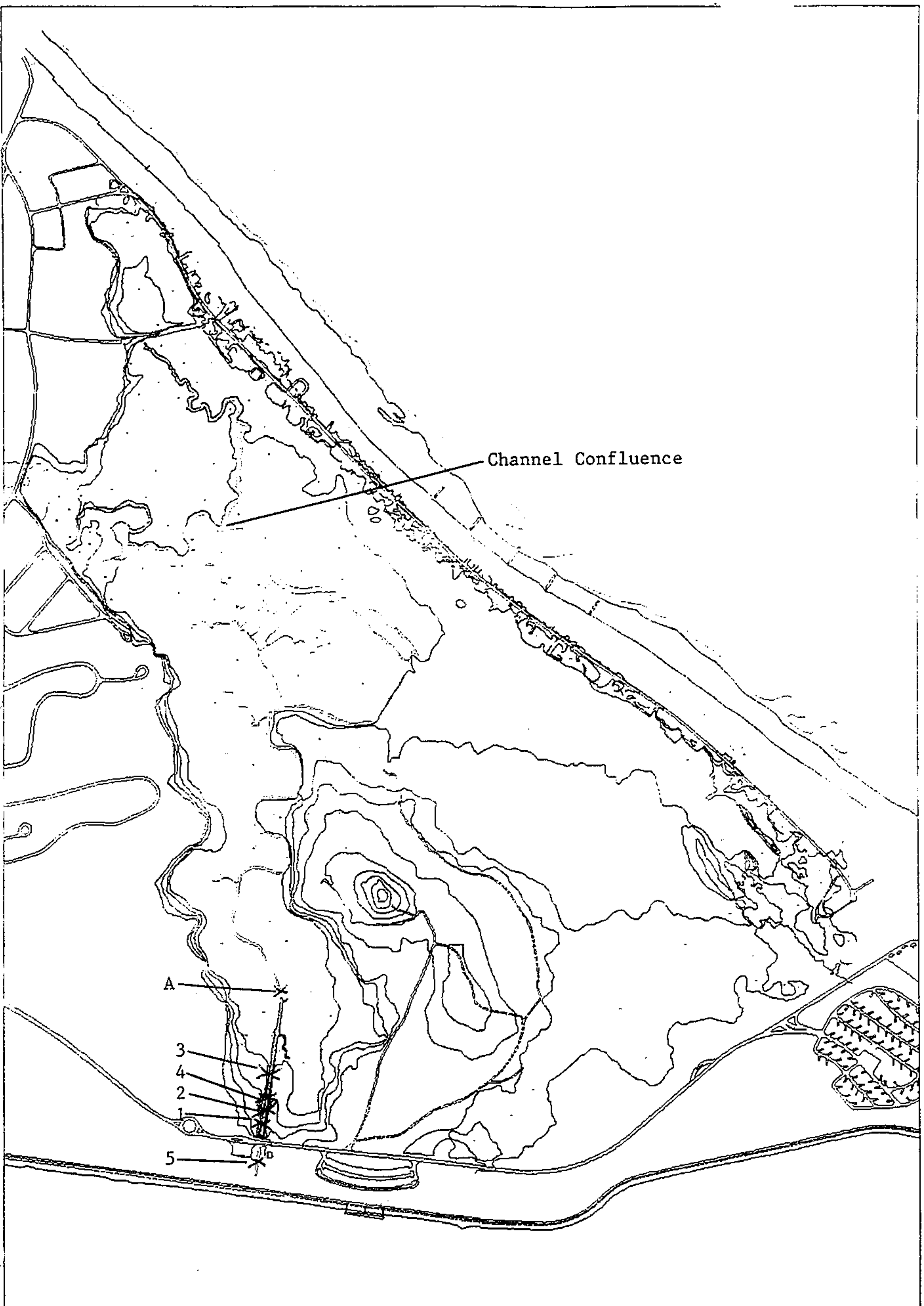


FIGURE 5. BENTHIC CORE SAMPLE LOCATIONS SAGAMORE MARSH RESTORATION PROJECT

observed entering the marsh/estuary through the culverts during an incoming tide.

The Cape Cod Canal contains marine habitat. It is an important fishery resource and supports a wide range of marine species and an important recreational fishery. Striped bass and bluefish are among the important recreational species in the Canal.

WILDLIFE

A list of birds, mammals, reptiles, and amphibians associated with the wetland habitats in the vicinity of the Sagamore Marsh is provided in Table 8.

Intertidal Habitats

Unvegetated intertidal habitat or tidal flats and creeks provide feeding, resting and migratory habitat for shorebirds, gulls and terns, wading birds, waterfowl, diving birds, and raptors. They are most important for shorebirds and, when flooded with shallow water, wading birds because these species feed almost exclusively in this habitat type (Whitlatch, 1982).

Open Water

Permanent estuarine water is present in the channel of the Sagamore Marsh. The permanent open water component of the salt marsh/estuarine system is important for wildlife. Open water provides important resting and feeding habitat for waterfowl and feeding habitat for wading birds.

Salt Marshes

Salt marshes are important wildlife habitats. Over 100 species of invertebrates including insects, snails and crabs have been found on a New England salt marsh. Although mammals are less abundant, small mammals such as meadow voles (Microtus pennsylvanicus), white-footed mouse (Peromyscus leucopus), and masked shrews (Sorex cinereus) use the dense mat of high marsh vegetation. Larger mammals such as raccoons (Procyon lotor), mink (Mustela vison), skunk (Mephitis mephitis), weasels (Mustela spp.), and muskrats (Ondatra zibethicus) feed on the marsh (Nixon, 1982). The seeds of the high salt marsh dominants (salt meadow grass, black grass, and spike grass) provide food for black ducks (Anas rubripes), Canada geese (Branta canadensis) and other waterfowl, marsh and shore birds, and small mammals. The shoots and rootstocks provide forage for muskrats, small mammals and waterfowl (Amos and Amos, 1985; NAD, ACOE, 1977; Niering, 1968). The only reptile present in any great numbers on the New England salt marsh is the diamond-backed terrapin (Malaclemys

TABLE 5
FISHES INHABITING GREAT SIPPEWISSETT SALT MARSH MASSACHUSETTS (FROM WERME 1981).*

Fishes that spend most of their lives within the marsh:

Common name	Scientific name
Atlantic silverside	*Menidia menidia*
mummichog	*Fundulus heteroclitus*
striped killifish	*Fundulus majalis*
sheepshead minnow	*Cyprinodon variegatus*
four-spined stickleback	*Gasterosteus aculeatus*
common eel	*Anguilla rostrata*

Fishes that use the marsh mostly as a nursery area:

winter flounder	*Pseudopleuronectes americanus*
tautog	*Tautoga onitis*
sea bass	*Centropristes striata*
alewife	*Alosa pseudoharengus*
menhaden	*Brevoortia tyrannus*
bluefish	*Pomatomus saltatrix*
mullet	*Mugil cephalus*
sand lance	*Ammodytes americanus*
striped bass	*Morone saxatilis*

*Listed in approximate order of abundance within each group.

TABLE 6
BIRD HABITAT USE-SPECIES ASSOCIATIONS IN NEW ENGLAND SALT MARSHES

(From Nixon, 1982 as provided by Ralph Andrews of the U.S. Fish and Wildlife Service.)

Nest and feed in high marsh:

- Sharp-tailed sparrow
- Long-billed marsh wren (*Typha* or *Phragmites*)
- Meadowlark
- Savannah sparrow (highest areas)
- Marsh hawk
- Short-eared owl (local)
- Black rail (rare)

Nest in high marsh, but feed in pools of *S. alterniflora* zone:

- Clapper rail
- Willet
- Black duck
- Blue-winged teal
- Canada goose
- Seaside sparrow

Nest in high marsh, but feed in open water:

- Gulls
- Terns

Nest in high marsh, but feed in open marsh:

- Yellowthroat
- Song sparrow
- Catbird
- Kingbird
- Redwing
- Grackle

Nest on woody islands; feed in the marsh:

- Herons
- Egrets
- Glossy ibis

Nest elsewhere; feed on insects over marsh:

- Swallow
- Chimney swift

terrapin) (Teal, 1986).

Birds are the most conspicuous of the salt marsh wildlife. Nixon (1982) presented a list (Table 6) of birds which use salt marshes based on information provided by the U.S. Fish and Wildlife Service.

Phragmites

Phragmites supports a less abundant and diverse wildlife community. It generally grows in less diverse stands and has relatively low value as a food item because of the coarseness of its stems and leaves and its hairy seeds. Phragmites does provide cover and nest sites for some species of birds such as red-winged blackbirds (Agelaius phoeniceus) and provides fall roosting sites for migrating tree swallows (Iridoprocne bicolor). The wildlife value of Phragmites includes food for muskrats, although of low quality, and insect production, which in turn serves as food for terrestrial and aquatic organisms (Howard et al., 1978; NAD, ACOE, 1977).

Shrub and Forested Swamp and Coastal Shrub Habitats

Shrub and forested swamps are valuable habitats for a large number of mammals, birds and amphibians. Golet et al. (1993) listed 24 species of amphibians, 18 species of reptiles, 119 species of birds, and 49 species of mammals as vertebrates observed in Northeastern red maple swamps.

Coastal shrub and dune habitats are valuable for a number of species of wildlife. They provide cover and nesting habitat for shorebirds, song birds, and gulls and terns and cover and forage areas for mammals and song birds (Woodhouse, 1982).

MOSQUITOES

Mosquitoes are part of the fauna of both freshwater marshes and salt marshes. While monitoring of mosquitoes has not been conducted at the project site, the potential mosquito populations at the site can be generally described. The present population in the area dominated by Phragmites would consist of freshwater varieties such as the house mosquito (Culex pipiens).

Aedes sollicitans is the most common of the salt marsh mosquitoes and probably inhabits the existing high marsh on the study site. Teal (1986) described its life history: "The marsh mosquito, (Aedes sollicitans), lays its eggs on wet mud in the higher marsh rather than the low marsh. The eggs develop to the hatching point, then wait until they are flooded by an extra high tide or heavy rain before hatching. In warm weather they can become adults in about one week, emerging from the pools in hordes." Nixon (1982) indicated of the salt marsh mosquito, "...the Aedes spp. which breed on the high marsh travel farther and feed more voraciously (at least on man and his domestic animals) than species which breed in areas that are more or less permanently flooded".

THREATENED AND ENDANGERED SPECIES

There are no known Federally listed or proposed threatened or endangered species under the jurisdiction of the U.S. Fish and Wildlife Service or National Marine Fisheries Service at the project site with the exception of occasional, transient bald eagles (<u>Haliaeetus</u> <u>leucocephalus</u>) or perigrine falcons (<u>Falco peregrinus</u>) (Correspondence dated October 25, 1995 and telephone conversation record dated January 19, 1996, Appendix EA-A).

The Massachusetts Natural Heritage and Endangered Species Program (MNHESP) has indicated that four-toed salamanders, a State Species of Concern, are present at the project site.

WATER QUALITY

The Cape Cod Canal and Sagamore Marsh are classified SB according to the Massachusetts Surface Water Quality Standards. Class SB waters are designated as habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they are suitable for shellfish harvesting with depuration. Dissolved oxygen is not less than 5.0 mg/l unless background conditions are lower and natural seasonal and daily variations above this level must be maintained. Class SB waters are free of suspended solids that would impair any assigned use, that are aesthetically objectionable, or that would impair the benthic biota or degrade the chemical composition of the bottom. Color and turbidity are to be maintained in concentrations that are not aesthetically objectionable or would not impair any assigned uses.

SEDIMENT QUALITY

The project site in the vicinity of proposed construction activities was surveyed for evidence of hazardous, toxic, or radiological waste; no evidence of such contamination was observed. Sediment chemistry samples were not collected for this project because sufficient existing information is available to conclude that the material to be excavated is suitable for unrestricted offsite disposal. Based on land uses in the vicinity of the site, the relatively clean uses of areas surrounding Sagamore Marsh, and the length of time since the material was placed in the site, there is no reason to expect contamination of the sediments to be excavated. The material excavated for the construction of channels will be disposed of in a suitable offsite landfill.

AIR QUALITY

The entire state of Massachusetts is designated a non-attainment zone of ozone (O_3) and is part of the Northeast Ozone Transport Region which extends northeast from Maryland and includes all six New England states. Non-attainment zones are areas where the National Ambient Air Quality Standards (NAAQS) have not been met. Nitric oxide (NO), hydrocarbons, oxygen (O_2), and sunlight combine to form ozone in the atmosphere. Nitrogen oxides are released during the combustion of fossil fuels.

HISTORIC AND ARCHAEOLOGICAL RESOURCES

An archaeological reconnaissance survey of the Cape Cod Canal project area was completed early in 1995 and included testing within the proposed study area. Several documented archaeological sites are located within and near the project location. They include the following:

19-BN-550 - A Late Archaic-Early Woodland Period site of unknown type which has been collected from over the years. Diagnostic projectile points and stone tools are the primary finds. Site is likely destroyed by road construction, cranberry cultivation and quarrying.

19-BN-227 - Workshop site of unknown temporal period. No other information.

19-BN-225 - A shellheap reported as destroyed in 1940. No other information.

In addition, the Corps identified two additional sites within the Sagamore Hill area known as Sagamore Hill Locus Numbers 1 and 2. Locus Number 1 consisted of a small lithic workshop which was probably a part of site 19-BN-227 and a temporary campsite, while Locus Number 2 indicated a small temporary camp with lithic maintenance activities. Both sites were listed as potential National Register of Historic Places listings and protective measures should be initiated if construction is planned in the vicinity of these sites. All sites are shown on Figure .

SECTION VI - ENVIRONMENTAL CONSEQUENCES

GENERAL

The purpose of this project is to restore the previously existing estuarine community and its value for fish and wildlife. Except for short term negative effects, this project will primarily have positive effects on the environment. The area of estuarine habitat including salt marsh will be increased; access to Sagamore Marsh by estuarine organisms will be greatly increased, thereby strengthening the ecologic link between the marsh and Cape Cod Bay; estuarine aquatic productivity will be partially restored; the majority of the relatively low value Phragmites will be replaced by higher value salt marsh plants; the value of the site for shellfish, fish, and wildlife will be increased; and the recreational and aesthetic qualities of the site will be improved. The effects of the project are described in detail in the following sections.

WETLANDS, VEGETATION, AND COVER TYPES

General

In general, the effect of the project on the vegetation community will be to reduce the amount of Phragmites and replace it with salt marsh vegetation. More detailed predictions of the vegetation community and the factors controlling the change in plant species composition are presented in the following paragraphs.

Construction Phase Effects

There will be temporary impacts to wetland and upland vegetation during the construction period. Vegetation removal in the two staging areas will temporarily disturb approximately 0.6 acre of upland vegetation (scrub oak, scarlet oak, white oak, black cherry, big-toothed aspen, red maple, bayberry, arrow wood, poison ivy, Virginia creeper, staghorn sumac, red cedar, grape, slough grass, fireweed, goldenrod, and other upland weeds and grasses). A small area of salt marsh (approximately 200 square feet) will be destroyed in the footprint of the temporary access road. The size of disturbance of the staging area and access roads will be limited to the minimum necessary for construction access and a line of erosion control devices will be established along the perimeter. These areas will be allowed to revegetate following construction and areas with severe slopes or disturbed soils with a high potential to impact water quality will be replanted to limit erosion.

Direct Effects

The most rapid and direct effect of the project on vegetation will be the displacement of salt marsh and upland vegetation lining the riprap channel. Only the east side of the existing channel will be replaced. The approximate area of salt marsh (primarily salt marsh cordgrass with some salt meadow grass, sea lavender, and common reed) directly altered by the project due to reconstruction of the riprap entrance channel is approximately 0.6 acre. This vegetation established on the edges of the channel after the channel was installed and similar habitat will likely reestablish itself over time when a new channel is constructed due to the low velocities that will occur with the project. The remaining vegetation on the west side of the channel may be affected by the change in hydrology after the project is constructed. About 0.4 acre of freshwater wetland at the northern end of the riprap channel will be destroyed and replaced by riprap and channel habitat.

Systemic Effects

The restoration of tidal flushing will result in a reduction in the abundance of Phragmites on the site and an increase in salt marsh vegetation. The change to a less desirable vegetation community as a result of a reduction in tidal flooding and soil water salinity has been observed at various locations in Connecticut (Niering and Warren, 1980; Roman et al., 1984; Bongiorno et al., 1984; and Sinicrope et al., 1990). Bongiorno et al. (1984) found that, three years following the restoration of tidal flow to the Pine Creek Salt Marsh in Connecticut, Phragmites declined from 11.3 plants/m^2 to 3.3/m^2 followed by a constant but less dramatic decline over succeeding years. Average Phragmites height declined from 182 cm to 75 cm over the three year period. Twelve other non-salt marsh plant species disappeared and salt marsh species increased in dominance. Similar results are expected at the Sagamore Marsh with nearly complete elimination of Phragmites in areas flooded eight times per month or more after 10 years.

The major goals of reintroduction of tidal flow with respect to the plant community are to increase the frequency of flooding and soil water salinity levels to eliminate common reed and restore conditions which favor the growth of salt marsh vegetation. The level of soil water salinity required to eliminate common reed and restore salt marsh is estimated at 20 parts per thousand (ppt) based on the pertinent literature (Howard et. al., 1978; Odum et. al., 1984; Mitsch and Gosselink, 1986; Garbisch, 1986; Sinicrope et. al., 1990).

To achieve this level of soil water salinity, tidal flooding must be restored and fresh soil water must be displaced by salt water. Salt water enters the salt marsh root zone through pulses of the groundwater (Hemmond and Fifield, 1982) and surface seepage during high tides (Carr and Blackley, 1986). The level of salinity in the marsh soil water is controlled by the frequency of tidal flooding of the soil pore spaces, the salinity of the tidal water, freshwater inflow, and evapotranspiration. The salinity of the tidal water at Sagamore Marsh is sufficient to restore salt marsh. The frequency of flooding can be controlled by the project features. The frequency of tidal flooding depends on the relationship between the ground surface elevation and tide height as influenced by hydrodynamic forces.

Based on evaluations conducted for the Incremental Analysis (Appendix C of the main report), at least eight flooding tides per month are necessary to maintain salt marsh at this site. Portions of the marsh above the elevation flooded by this tide up to the highest astronomic tide level will likely be composed of a mixture of Phragmites and salt marsh vegetation. The lower limit of the salt marsh should occur at about the mean tide level.

The change in area of each vegetation type has been estimated by examining the aerial photography for low areas and predicting the acreage of salt marsh on lower portions of the marsh based on the results of the Incremental Analysis.

Predictions of the post-project plant community for the recommended alternative are shown in Table 7. Column 1 of Table 7 shows the existing vegetation types throughout the marsh and bordering wetlands. Column 2 shows the expected vegetation types when the project is complete. The anticipated vegetation pattern approximately ten years following project implementation is shown in Figure 6.

The post-project site may not exactly replicate the wetland types as they historically occurred at the Sagamore Marsh. Subsidence normally occurs when tidal flow is curtailed under similar conditions (Roman et al., 1984). During a 17-year period when a salt marsh was diked in Oregon the surface subsided 30 to 40 cm due to compaction and loss of soil buoyancy. Ten years after breaching the dike to restore the marsh, accretion had raised the topography only 2 to 5 cm throughout most of the site resulting in the area of low salt marsh being much larger than that present before diking (NRC, 1992). This suggests that, barring differences in the tidal regime as a result of the new location of the inlet, the area of low marsh with the project could be larger than the historic area.

Change in Wetland Area

A concern was expressed that the project would result in an increase in the area of wetland at the expense of surrounding upland areas. This would increase the area of privately owned land subject to regulation as wetland. This effect is expected to be minimal to non-existent because nearly all of the wetland edge is bordered by shurb or forested swamp. These wetland types extend up the slope bordering the common reed marsh.

TABLE 7
EXISTING AND PREDICTED VEGETATION AREA AT THE SAGAMORE MARSH

Vegetation/Community Type	1 Existing (Acres)	2 Predicted Future Veg. (Acres)
Tidal creeks	2.3	2.4*
Permanent ponds	1.3	1.3
Salt marsh (total)	9.4	59.4
Common reed marsh (total)	87.2	57.8
Mixed common reed and shrubs	9.0	5
Freshwater emergent wetland	0.6	0.6
Forested/shrub swamp	78.7	62
TOTALS	188.5	188.6

* Includes 0.1 acre increase for the increase in channel size.

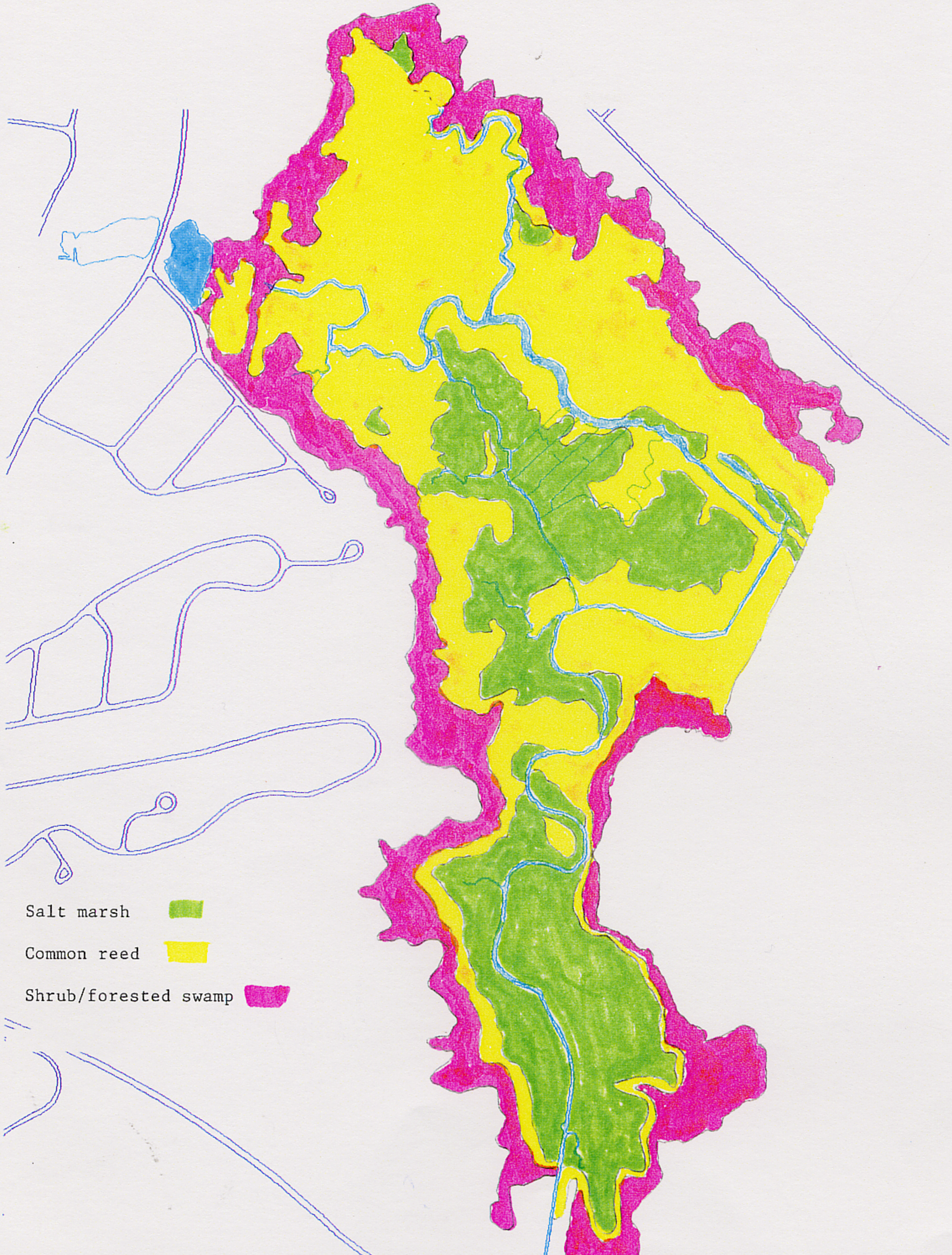


FIGURE 6. APPROXIMATE FUTURE
VEGETATION PATTERN WITH THE PROJECT

Particularly in the upstream portions of the marsh where the change in tide range will be small, the change in the height of the high tides (<0.5 ft) is expected to fall within this vertical range of wetland vegetation.

Productivity

In addition to the change in plant species and habitat type from Phragmites dominated freshwater marsh to estuarine salt marsh that will restore estuarine productivity, the increase in tide range over the existing salt marsh may increase its productivity. Researchers have described a relationship between tidal range and marsh productivity (Odum, 1974; Steever at al., 1976; and Odum 1980). Steever et al. (1976) indicated that the artificial restriction of the tidal prism may adversely affect production of salt marsh cordgrass. They found correlational evidence that there is a 580 g/m^2/year increase in productivity per meter increase in tide range. Waterlogged soil conditions limit the productivity of salt marsh cordgrass (Mendelsshon and Seneca, 1980). Tides are believed to provide an energy subsidy to the marsh system which increases with tidal range. These researchers focused on the salt marsh cordgrass marsh, but the concept may also apply to a lesser degree to the high marsh, particularly those portions of the high marsh close to the creekbanks.

Short salt marsh cordgrass is typically abundant in areas that are subject to waterlogged soils and is less productive than salt meadow under these conditions. The increase in soil drainage with the project in areas near the outlet should result in an increase in the relative abundance of salt meadow grass along the main channel where existing salt marsh is located. In the areas of waterlogged soils along the existing channel, the increase in tide range should result in an increase in the productivity of the marsh. However, the small increase in the level of low tides in the interior of the marsh over existing conditions suggests the productivity of this portion of the marsh will be less than optimum.

Sea Level Rise

Salt marshes maintain their height relative to sea level by accumulating organic and inorganic sediments. Accumulation of organic material from the salt marsh plants provides the majority of the material composing the salt marsh peat, but the inorganic component is important for its contribution to the composition of the peat, in particular its bulk density. A minimum contribution of inorganic sediment from marine, upstream freshwater, and upland sources is required to allow the marsh to maintain itself with sea level rise.

The installation of culverts and channel improvements will increase the potential for sediment input from the marine source (i.e., the Cape Cod Canal), while the other sources will not be affected by the project. Therefore, potential sediment accumulation should increase. Over the long term, with or without the new culverts, the marsh would experience longer and longer term flooding as sea level rises, but the culvert project should not detrimentally affect the condition of the marsh with sea level rise. The presence of tide gates will allow tide heights in the marsh to be controlled.

SHELLFISH AND BENTHIC INVERTEBRATES

Construction Effects

The project has the potential to have a temporary adverse effect on shellfish and other benthic invertebrates during construction. Relatively immobile benthic organisms in the direct footprint of construction activities will be destroyed. However, larval and adult recruitment will quickly recolonize the disturbed benthic substrates. The remainder of the benthic community will experience effects due to an increase in turbidity and suspended solids.

The benthic community in the vicinity of the project consists of detritivores, predators, and suspension feeders. All have the ability to move small distances in response to shifting substrates and small changes in surface level. Suspension feeders, including shellfish, feed on materials suspended in the water column and are therefore affected by changes in turbidity. Suspension feeders are able to adjust to short term increases in suspended sediments by temporarily closing their feeding apparatus. When turbidity levels return to normal between short term periods of soil disturbance, feeding resumes. Therefore, construction impacts to benthic invertebrates and shellfish are expected to be minimal.

Long Term Effects

The project will have long term and permanent effects on benthic resources. Benthic invertebrates and plants in the area of the riprap channel to be widened and deepened will be destroyed. This will result in the loss of existing benthic resources, including species living in the shallow sediments and those living on existing hard substrates (e.g., American oysters and blue mussels) in about 0.2 acre of channel bottom. The new stone protection will support a community adapted to hard substrate until sediment again fills the channel bottom. If or when the channel bottom is covered with sediment a community similar to the existing benthic community will form.

The long term effect of the project will be to increase the area of available benthic habitat by increasing the size of the riprap channel and improve aquatic productivity and the quality of benthic resources. The increase in detrital export (a building block of estuarine communities) as a result of the increase in salt marsh area is expected to increase the capacity of the site to support a productive benthic community.

Changes in salinity in upstream portions of the channel are expected to be small because the salinity is already quite high (ca. 23 ppt.). However, the community should experience a small shift toward a community of higher salt tolerance.

FISH

Construction Effects

The project will have minor effects on finfish during construction. Since fish are mobile they can avoid the relatively small area of increased turbidity that may result from construction. Fish that pass through the culverts during construction may be exposed to higher turbidity levels as a result of soil disturbance during construction. However, the increase in turbidity is expected to slight due to erosion control and construction sequencing. Estuarine fish are tolerant of periodic increases in turbidity and can pass through areas of higher turbidity. There are no known anadromous fish runs at the project site.

Long Term Effects

The project will have a positive long term effect on fisheries. The overall quantity of estuarine aquatic habitat available to fish will increase. In addition, the increase in estuarine productivity (e.g., detrital export) will benefit fish which feed directly on the detritus formed by the salt marsh and benthic organisms in the intertidal area. The improvement in aquatic productivity and populations lower in the food web will enhance the support of fish higher in the food web, including commercial fish.

WILDLIFE

Construction Effects

For all types of wildlife, there will be temporary disturbance of habitat during the estimated nine-month construction period. Some species may temporarily leave the area, but overall there will be a minor temporary decrease in the capacity to support wildlife populations during the construction time frame.

Table 8. Predicted Changes in Wildlife Use as a Result of Restoring Salt Marsh and Estuarine Habitat at the Sagamore Marsh. "+" indicates an increase in habitat value or positive effect on wildlife populations; "-" indicates a decrease in habitat value or negative effect on wildlife populations; "N" indicates a negligible change; and "NA" indicates that the species does not use the Sagamore Marsh for the activity listed and is not expected to use it after the restoration project.

BIRDS

	Nesting	Feeding	Resting	Overall
Perching birds				
Red-winged blackbird1&2	-	+	-	-
Common yellowthroat1&2	+	+	+	+
Yellow warbler1	N	N	N	N
Song sparrow1&2	+	+	-	+
Willow flychatcher1	-	N	-	-
Gray catbird1&2	+	+	-	+
Sharp-tailed sparrow1&2	+	+	+	+
American robin1	N	N	N	N
European starling1	N	N	N	N
House finch1	N	N	N	N
American goldfinch1	N	N	N	N
Cedar waxwing1	N	N	N	N
Common grackle1	N	+	N	+
Swamp sparrow1	N	-	-	-
Northern cardinal1	N	N	N	N
Rufous-sided towhee1	N	N	-	-
Purple finch1	N	N	N	N
Mourning dove1	N	N	N	N
Black-billed cuckoo1	N	N	N	N
Carolina wren1	-	-	-	-
Marsh wren1&2	+	+	+	+
Black-capped chickadee1	N	N	N	N
Eastern phoebe1	N	N	N	N
Red-eyed vireo1	N	N	N	N
Yellow-rumped warbler1	N	+	+	+
American tree sparrow1	NA	N	N	N
Seaside sparrow1&2	+	+	+	+
Meadowlark2	+	+	+	+
Savannah sparrow2	+	+	-	+
Kingbird2	+	+	+	+
Grackle2	N	+	-	+
Swallow2	N	-	-	-
Chimney swift2	N	N	N	N
Belted kingfisher4	N	+	N	+

	Nesting	Feeding	Resting	Overall
Shore birds				
Semipalmated sandpiper1	NA	+	+	+
Black-bellied plover1	NA	+	+	+
Sanderling1	NA	N	N	N
Dunlin1	NA	+	+	+
Killdeer1	N	+	+	+
Willet2	+	+	+	+
Waterfowl				
American black duck1&2	+	+	+	+
Mallard1	N	+	+	+
Canada goose1&2	+	+	+	+
Blue-winged teal2	NA	+	+	+
Green-winged teal3	NA	+	+	+
American widgeon1	NA	+	+	+
Hooded merganser1	N	+	+	+
Red-brested merganser1	NA	N	N	N
Gadwall1	N	+	+	+
Bufflehead1	NA	N	N	N
Mute swan1	N	N	+	+
Wading birds				
Great blue heron1&4	NA	+	+	+
Great egret1	NA	+	+	+
Snowy egret1	NA	+	+	+
Green-backed heron3	N	+	+	+
Black-crowned night heron1	NA	+	+	+
Yellow-crowned night heron1	N	+	+	+
Glossy ibis2	NA	+	+	+
American bittern1	+	+	+	+
Virginia rail1	N	+	+	+
Clapper rail2	+	+	+	+
Gulls and Terns				
Herring gull1	NA	+	+	+
Great black-backed gull1	NA	+	+	+
Terns2	+	+	+	+
Raptors				
Northern harrier1&2	NA	+	N	+
Short-eared owl2	NA	+	+	+
Snowy owl	NA	+	+	+

MAMMALS

	Cover	Food	Overall
River otter3	-	+	+
Mink2,3&4	-	+	+
Long-tailed weasel3	N	+	+
Red fox3	N	+	N
Gray fox3&4	-	+	N
White-tailed deer3&4	-	+	N
Muskrat2&3	-	+	+
Raccoon2,3&4	-	+	+
Meadow jumping mouse2	-	+	N
Meadow vole2&3	N	+	+
Star-nosed mole3	-	-	N
Virginia opposum3	N	N	N
Masked shrew2	N	N	N
Short-tailed shrew3	N	N	N
Big brown bat3	N	-	-
House mouse2&3	N	+	N
Norway rat3	N	N	N
Striped skunk2,3&4	N	+	+
White-footed mouse	-	+	N

REPTILES AND AMPHIBIANS

	Cover	Food	Overall
Painted turtle3	-	-	-
Spotted turtle3	-	-	-
Snapping turtle3	-	-	N
Diamondback terrapin3	NA(+)	NA(+)	NA
Northern watersnake3	N	N	N
Salamanders3	-	-	N
Frogs3	-	-	N

[1] - Eddleman, W.R. 1993. Performance report: Galilee Bird Sancturay avian species and habitat associations. Federal Aid in Wildlife Investigation, Project No. W-23-R-32, III, 3. (The Galilee Bird Sanctuary has a similar combination of habitat types to the Sagamore Marsh.)

[2] - Nixon, S.W. 1982. The Ecology of New England High Salt Marshes: A Community Profile. FWS/OBS-81-55. U.S. Fish and Wildlife Service. Office of Biological Services, Washington, D.C. 70 pp.

[3] - Odum, W.E., T.J. Smith III, J.K. Hoover, and C.C. McIvor. 1984. The ecology of tidal freshwater marshes of the United States east coast: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-83/17. 177pp.

[4] - Reported or observed on-site.

Long Term Effects

Effects of the project on particular wildlife species are summarized in Table 8. The quality of wildlife habitat is based on the interrelationship (juxtaposition and interspersion) between three key elements (food, cover, and water). Juxtaposition refers to the distribution between the requirements of a species (i.e., food, cover and water) in relation to each other and the area normally travelled by a species. Interspersion refers to the distribution of habitat components in relation to the habitat as a whole (King, 1938).

The relationship between habitat elements will change with the restoration project. As a result, there will be a change in the relative abundance of the various species of wildlife using the site. However, none of the vegetation types on the site will be completely eliminated as a result of the project, so all of the species presently using the site are expected to remain, although at different population levels.

In general, the change in the vegetation types and the relationship between vegetation types will improve. Phragmites, which primarily provides cover, will reduce in area, while salt marsh plant species which provide food and limited cover will increase in area. The increase in the area of salt marsh will increase the forage area of the wetland improving the elements of juxtaposition and interspersion. Use of the site by some species associated with the shrub and Phragmites components of the habitat may decline with the reduction in these habitat types; however, since cover is only one of the necessary components of the habitat, the overall quality of the habitat for even these species may improve.

Birds

The change from Phragmites dominated marsh to salt marsh will result in an increase in bird species that nest and feed in or over the salt marsh and, potentially, a decrease in the species associated with Phragmites and shrub habitats. The following species will probably increase in nesting and abundance: seaside sparrows, sharp-tailed sparrows, meadowlarks, black ducks, and Canada geese. The following groups of birds will experience an increase in available feeding area: herons, egrets, ibis, gulls, and terns.

Even species such as the red-winged blackbird which nest in Phragmites and shrub habitats may increase in number as the relationship between the food and cover elements of the habitat changes. The decrease in cover habitat for these types of species is expected to be insignificant.

Mammals

Many of the mammals inhabiting the Sagamore Marsh will benefit from the increase in feeding habitat available following restoration of estuarine habitat. Small mammals such as meadow voles and white-footed mice may experience a decrease in useable habitat area, but an increase in the quality of their foraging habitat. Larger mammals such as deer, raccoons, muskrats, skunks, otters, and mink will experience a decrease in available cover, but an increase in the quality of the feeding component. They are expected to experience overall positive impacts.

MOSQUITOES

The restoration of tidal flow may change the type of mosquitoes inhabiting the site from freshwater varieties to the more aggressive salt marsh mosquito. However, restoration of tidal flow will also enhance the ability of managers to manage the mosquito population and may result in an overall reduction in the number of mosquitoes.

Hellings and Gallagher (1992, in Nature Conservancy, 1993) indicated that the monitoring and control of mosquito breeding is nearly impossible in dense Phragmites stands. Steinke (1987) indicated that when the town of Fairfield, Connecticut constructed a dike which restricted tidal flushing of a salt marsh, the State Mosquito Control Unit discontinued maintenance on mosquito ditches because it was impossible to maintain them without the flushing action of the tides. When Phragmites moved in, even spraying of pesticides was stopped because of the lack of access in the dense stands. This led the State to describe the ditched and diked marshes as producing more mosquitoes than if the marshes were left in their original condition. The Sagamore Marsh is in a similar condition to the marsh described in Connecticut.

The state of Massachusetts will institute Open Marsh Water Management (OMWM) or other measures to control mosquitoes once the tidal flow is restored. OMWM is a system for controlling mosquitoes where small ponds with permanent reservoirs are created to provide habitat for mosquito-larvae-eating fish. The ponds are connected to other mosquito breeding depressions by radial level ditches (Payne, 1992). When the tide rises and floods mosquito breeding habitat, the larvae eating fish travel to the hatching sites and eat the larvae before they can transform to the adult phase. This technique can result in a 95% reduction in salt marsh mosquito populations (Capotosto, P.M., Connecticut Department of Environmental Protection, Wetlands Restoration Unit, pers. comm., February 1994). With OMWM the project is not expected to create mosquito problems and may result in an overall reduction in mosquitoes.

THREATENED AND ENDANGERED SPECIES

There are no known Federally listed or proposed threatened or endangered species under the jurisdiction of the Fish and Wildlife Service or National Marine Fisheries Service at the project site with the exception of occasional, transient bald eagles (Haliaeetus leucocephalus) or perigrine falcons (Falco peregrinus) (Correspondence dated October 25, 1995 and January 19, 1996). Therefore, there will be no adverse impact on Federally listed threatened or endangered species from any project alternative.

The Massachusetts Natural Heritage and Endangered Species Program (MNHESP) has indicated that four-toed salamanders, a State Species of Concern, are present at the project site. Preliminary information from the MNHESP indicates the the populations are located above the level of tidal influence that will occur with the project. Therefore, there will be no adverse effect on this species.

WATER QUALITY

There may be a temporary short term increase in turbidity and suspended solids in the vicinity of the project during construction which could temporarily affect water quality. A sediment core from the bank on the west side of the channel indicated that the material is composed of from 5-30 percent silt. In order to minimize potential construction phase water quality impacts, the channel will be constructed in segments. After each segment is constructed, the banks will be protected with riprap so that the smallest possible area is exposed to erosion. Appropriate controls on erosion and sedimentation will be employed throughout construction to isolate areas of disturbed soils and construction activity. In addition, construction will take place during the fall, winter, and spring when the metabolic activity of organisms that could be affected by water quality is lowered.

AIR QUALITY

The project will have essentially no long-term impacts on air quality. During construction, equipment operating on the site will emit pollutants including nitrogen oxides which can lead to the formation of ozone. Massachusetts has no permit requirements for construction projects. In order to minimize air quality effects during construction, construction activities will comply with the Massachusetts Air Pollution Control Regulations pertaining to Dust, Odor, Construction and Demolition (310CMR 7.09), Noise (310CMR 7.10), and Motor Vehicle Emissions (310CMR 7.11(1)).

GROUNDWATER WELLS AND SEPTIC SYSTEMS

A groundwater analysis was performed to assess the potential effect of increased high tide stages on septic systems and the salinity of water supply wells. Details on these studies are provided in Section 7.4 of the feasibility report and Appendix E.

The effect of marsh restoration on septic systems was analyzed by measuring the tidal range in the marsh channels and the tidal pulse in the aquifer beneath the marsh sediments. The evaluation concluded that the increased tide levels resulting from larger culverts would not have any impact on septic systems adjacent to the marsh. Groundwater levels are not expected to increase more than 0.1 to 0.2 feet immediately adjacent to the marsh channels, and less away from the channels. Separations of three, four, or five feet between the water table and the bottom of the leach field were required for leach fields in Bourne and Sandwich depending on the regulation in place at the time of construction. The small increase in groundwater levels would not impact the performance of leach fields that meet the separtion requirements.

The effect of marsh restoration on the salinity of the North Sagamore Water District's "Beach Well"and the Department of Environmental Management's wells at Scusset Beach State Park were analyzed by performing an aquifer test on the Beach Well and applying a numerical model of groundwater flow in the vicinity of Sagamore Marsh. This evaluation concluded that based on the direction of groundwater flow and the nature of the aquifers there would no adverse effect from the restoration of tidal flow.

FLOODING

The project has been designed to avoid an increase in flooding potential of surrounding developed areas (see Section 7.4 of the main report and the Hydrology/Hydraulics Appendix). All culverts will be equipped with sluice gates and a backup control system that can be closed in advance of an approaching storm.

A monitoring plan will be conducted to ensure that the project does not cause flooding of adjacent properties or septic systems or affect the salinity of the North Sagamore Water District beach well. If impacts are detected, the amount of water enteringthe marsh can be reduced to eliminate the impact. The monitoring plan is described in Appendix F.

HISTORIC AND ARCHAEOLOGICAL RESOURCES

According to the most current project vicinity map, the selected alternative of restoring salt marsh and estuarine habitat to the area north and west of Sagamore Hill should not impact upon sites 19-BN-227 and Sagamore Hill Locuses 1 and 2. Site number 19-BN-550 is located just outside of the study area in the extreme northwest corner. Tidal flows will not extend to this location. A review of the prehistoric site files at the Massachusetts Historical Commission indicated that this site has most likely been disturbed or destroyed by road construction, cranberry cultivation, and quarrying. Protective measures and/or the professional supervision of an archaeologist on-site are not required as the remaining sites are either situated at higher elevations or are outside of the range of project actions or impacts.

Sites of historic, architectural or archaeological significance as defined by the National Historic Preservation Act of 1966, as amended should not be impacted by the proposed salt marsh restoration. The Massachusetts State Historic Preservation Officer (MA SHPO) is expected to concur to these determinations.

RECREATION AND AESTHETICS

During construction, there will be temporary impacts to the Canal Service Road (bike path) along the Canal. Traffic along this path will be rerouted across a temporary pathway while the downstream culvert is being installed. Once the downstream culverts are installed and the bike path is reconstructed, car and recreational vehicle traffic will be rerouted over the same crossing while the upstream culvert is installed.

The project should incrementally improve the quality of recreational as well as commercial fisheries due to improvements to fish habitat.

The reduction in the coverage of common reed in the marsh and its replacement with a more open (salt marsh) landscape type will improve the aesthetic value of the site and its value for passive recreational use such as bird watching.

A concern was expressed that the proposed project could increase the "rotten egg" odor sometimes associated with salt marshes. Hydrogen sulfide odor occurs when bottom deposits within an estuarine system release compounds containing sulfide. There is little oxygen below the surface layers of the sediment so organic material is decomposed by anaerobic (without oxygen) bacteria. These bacteria use sulfates rather than oxygen for their metabolic processes creating hydrogen sulfide and other sulfide compounds. Sulfides are converted to less odorous compounds in the aerobic portion of the marsh sediments and aerobic water. Where there is excessive buildup of organic material or poor flushing, anaerobic decomposition is more prevalent and an odor problem can occur. Disruption of flushing can contribute to the buildup of sulfides and associated odors (Bella, 1977).

Teal and Teal (1969) indicated that sick marshes may have a hydrogen sulfide odor, but that this odor is very faint in a healthy marsh. Since the proposed project will improve flushing of the marsh system and oxygenation of the sediments, it is not expected to increase hydrogen sulfide odors. However, a temporary increase in the release of free sulfides can occur when bottom deposits are physically disturbed (Bella, 1977); therefore, there may be an increase in hydrogen sulfide odor during construction.

TRAFFIC

The project will have minor temporary effects on traffic during the construction period. Removal of excavated material will require apporximately 150 dump truck trips to the Bourne Landfill. Traffic impacts will be minimized by scheduling construction to avoid the high use summer tourism season.

SECTION VII - SUSTAINABLE DEVELOPMENT; ACTIONS TAKEN TO MINIMIZE ADVERSE EFFECTS ENVIRONMENTAL IMPACTS

SUSTAINABLE DEVELOPMENT

Since this is an environmental restoration project, it involves changes to existing development (the Canal) to improve the quality of the environment. The restoration project itself is sustainable development in terms of its environmental effects since it will improve the quality of aquatic resources it affects.

ACTIONS TO MINIMIZE ADVERSE EFFECTS ON THE ENVIRONMENT

A number of design and construction requirements have been made to minimize adverse effects on the environment. Those factors requiring specific actions in later project phases are highlighted in this section.

The project has been designed to ensure that developed uplands will not be impacted by flooding. The set of culverts through the Canal Service Road or bike path will be equipped with sluice gates and a backup flow control system to control the level of tidal water during coastal flooding events.

Excavation for channel widening will be restricted to the east side of the channel to minimize impacts to salt marsh on the west bank of the channel. Stone protection will be replaced up to elevation 5 ft NGVD on the east bank. The remainder of this bank up to existing grade will be topsoiled and hydroseeded with an erosion control mixture containing switchgrass (*Panicum virgatum*).

The size of staging areas and access roads will be minimized (30-foot wide access road clearing). Work areas will be surrounded by erosion control devices.

Construction will take place during the 9-month period between August 1 and May 1 with the culvert and channel work occurring after October 1. A temporary road will be constructed across the channel to allow continued access to areas east of the construction area. To maintain tidal flow and freshwater outflow during the construction period, a temporary 48-inch corrugated metal pipe (CMP) will be placed in the channel under the temporary road between the two existing culverts. Flow will be conducted around each of the existing culverts during excavation and replacement by installing metal sheeting. The channel will be constructed in segments to minimize exposure of disturbed earth to tidal flow. Segments will be excavated, then stabilized with riprap before following segments are excavated.

The following general sequence will be followed: 1) Install erosion controls and clear staging areas; 2) construct upstream channel segment; 3) install bypass CMP and roadway; 4) install bike path culvert and gates; 5) install Scusset Beach Road culvert; 6) construct downstream channel segment.

In order to minimize potential construction phase water quality impacts, the channel will be constructed in segments. After each segment is constructed, the banks will be protected with riprap so that the smallest possible area is exposed to erosion. The stone from the existing riprap will be reused on-site. Excavated material that can not be reused for construction will be disposed of at the town landfill or in a suitable offsite upland location.

Mosquito control will be implemented as needed by the local sponsor to ensure that the restoration of tidal flow does not increase mosquito populations.

MONITORING

Wetlands: salt marsh. To ensure successful salt marsh restoration, appropriate levels of surface flooding and soil drainage must occur.

Salt marsh plants require surface flooding and soil drainage within certain limits. The marsh surface and soil near the creekbanks should be flooded and drained by tides. Further from the creeks, the marsh surface should be flooded and drained during each flooding tidal cycle. To establish salt marsh vegetation, the marsh should be flooded between eight times monthly and once daily.

The Corps will establish approximately ten permanent sample stations at two marsh transects (Transect 1 and a new transect between Transects 2 and 4). Record the marsh surface elevation, depth of soil water during low tide, depth of flooding relative to surface elevation at high and low water during spring and neap tide phases, plant species composition, percent cover, height and density of common reed, and height of salt marsh cordgrass. Sampling will be conducted prior to project implementation, immediately following implementation, and during August of each of the five years following implementation.

Vegetated shallows: eelgrass. The main channel in the Sagamore Marsh currently supports dense eelgrass (*Zostera marina*). To ensure the continued vigor of the eelgrass, permanent flooding of the channel bottom (subtidal habitat) is recommended. While eelgrass grows intertidally, it is desirable and may be essential to maintain some permanent water (at least one foot) in the main channel at least over the area where eelgrass presently occurs.

The Corps will establish three permanent plots. Measure percent cover, height, and density of eelgrass plants during August of each year. Sampling will be conducted prior to construction and for a period of three to five three years depending on sampling results.

Four-toed salamanders. Four-toed salamanders, a State-listed rare species, are present at the project site. To ensure that this species is not impacted by the project, the elevation of the four-toed slamander population will be surveyed early in the Plans and Specifications phase of the project. This information will be used to determine whether adjustments are required to avoid impacting the salamanders. Following implementation, the monitoring will be conducted to ensure that four-toed salamanders are not impacted. Monitoring will consist of: vegetation surveys to quantify the type and extent of habitat available to the species (both baseline and post-implemenation surveys will be conducted); salinity monitoring in the vicinity of the populations; and annual population surveys.

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IX. COMPLIANCE WITH ENVIRONMENTAL FEDERAL STATUTES AND EXECUTIVE ORDERS

Federal Statutes

1. Preservation of Historic and Archaeological Data Act of 1974, as amended, 16 U.S.C. 469 et seq.

Compliance: Not Applicable; project does not require mitigation of historic or archaeological resources at this time.

2. Clean Air Act, as amended, 42 U.S.C. 7401 et seq.

Compliance: Massachusetts has no permit requirements for construction projects. Construction activities will comply with appropriate portions of the Massachusetts Air Pollution Control Regulations. Complaince with the State Implementation Plan and Public Notice of the availability of this report to the Regional Administrator of the Environmental Protection Agency for review pursuant to Sections 176c and 309 of the Clean Air Act signifies compliance with this act.

3. Clean Water Act of 1977 (Federal Water Pollution Control Act Amendments of 1972) 33 U.S.C. 1251 et seq.

Compliance: A Section 404(b)(1) Evaluation and Compliance Review have been incorporated into this report. An application shall be filed for State Water Quality Certification pursuant to Section 401 of the Clean Water Act.

4. Coastal Zone Management Act of 1972, as amended, 16 U.S.C. 1431 et seq.

Compliance: A CZM consistency determination shall be provided to the State for review and concurrence that the proposed project is consistent with the approved State CZM program to the maximum extent practicable.

5. Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq.

Compliance: Coordination with the U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) has yielded no formal consultation requirements pursuant to Section 7 of the Endangered Species Act.

6. Estuarine Areas Act, 16 U.S.C. 1221 et seq.

Compliance: Not applicable; this report is not being submitted to Congress.

7. Federal Water Project Recreation Act, as amended, 16 U.S.C. 4601-12 et seq.

Compliance: Public Notice of the availability of this report to the National Park Service (NPS) and Division of Planning relative to the Federal and State comprehensive outdoor recreation plans signifies compliance with this Act.

8. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq.

Compliance: Coordination with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and Massachusetts Division of Fisheries and Wildlife signifies compliance with the Fish and Wildlife Coordination Act.

9. Land and Water Conservation Fund Act of 1965, as amended, 16 U.S.C. 4601-4 et seq.

Compliance: Public Notice of the availability of this report to the National Park Service (NPS) and the Massachusetts Office of Planning and Development relative to the Federal and State comprehensive outdoor recreation plans signifies compliance with this Act.

10. Marine Protection, Research, and Sanctuaries Act of 1972, as amended, 33 U.S.C. 1401 et seq.

Compliance: Not applicable; project does not involve the transportation nor disposal of dredged material in ocean waters pursuant to Sections 102 and 103 of the Act, respectively.

11. National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470 et seq.

Compliance: Coordination with the State Historic Preservation Office determined that no historic or archaeological resources would be affected by the proposed project.

12. National Environmental Policy Act of 1969, as amended, 42 U.S.C. 4321 et seq.

Compliance: Preparation of this environmental assessment signifies partial compliance with NEPA. Full compliance shall be noted at the time the Finding of No Significant Impact is issued.

13. Rivers and Harbors Act of 1899, as amended, 33 U.S.C. 401 et seq.

Compliance: No requirements for Corps' projects or programs authorized by Congress.

14. Watershed Protection and Flood Prevention Act, as amended, 16 U.S.C. 1001 et seq.

Compliance: Not Applicable.

15. Wild and Scenic Rivers Act, as amended, 16 U.S.C. 1271 et seq.

Compliance: Not Applicable; project is located within the marine environment.

Executive Orders

1. Executive Order 11988, Floodplain Management, 24 May 1977 amended by Executive Order 12148, 20 July 1979.

Compliance: The project has been designed to minimize potential harm to or within the floodplain. Circulation of this report for public review fulfills the requirements of Executive Order 11988, Section 2(a) (2).

2. Executive Order 11990, Protection of Wetlands, 24 May 1977.

Compliance: This restoration project preserves and enhances the natural and beneficial values of the affected wetlands and includes all practicable measures to minimize harm to wetlands. The Corps of Engineers has considered factors relevant to the project's effect on the survival and quality of the affected wetland. The project therefore complies with this Executive Order.

3. Executive Order 12114, Environmental Effects Abroad of Major Federal Actions, 4 January 1979.

Compliance: Not Applicable; project is located within the United States.

Executive Memorandum

1. Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing NEPA, 11 August 1980.

Compliance: Not Applicable; project does not involve nor impact agricultural lands.

Finding of No Significant Impact
(FONSI)

After careful consideration of the information presented in this Environmental Assessment (EA), it is my conclusion that development of the proposed project is in the best overall public interest. Implementation of the proposed project would not require a significant commitment of physical, natural, or human resources.

Points considered include the effect of placing side-by-side culverts equipped with water level control gates through the Cape Cod Canal bike path/access road and Scusset Beach Road and widening and deepening the existing riprap outlet channel. The culverts will have a cross-sectional dimensions of approximately 6' X 12' and will be equipped with tide gates to control the level of flooding in the marsh and surrounding area. The channel will be approximately eight-feet wider than the existing channel for a bottom width of approximately twelve-feet. Excavated material will be disposed of off-site at a landfill or other non-wetland location. This action will result in the restoration of approximately 50 acres of salt marsh.

In my evaluation, this EA has been prepared in accordance with the National Environmental Policy Act of 1969. The determination that an Environmental Impact Statement is not required is based on the information contained in the EA showing the following considerations:

1. The proposed plan will result in a net gain in wetland functions and values and estuarine habitat productivity and area.

2. The proposed plan will not adversely impact any Federally listed threatened or endangered species or cultural resources. Sufficient monitoring is included in the project to ensure that four-toed salamanders, a Massachusetts listed rare species, will not be adversely affected by the project.

3. A Clean Water Act, Section 404 (b)(1) Evaluation was prepared for this project. Both Water Quality Certification and CZM consistency concurrence will be obtained.

4. Impacts associated with the proposed work will be minimal, consisting of temporary turbidity and changes in habitat types, but the project will have substantial net positive ecological effects.

5. No significant impacts will be caused by the proposed project. It will not increase flooding potential of surrounding developed upland areas, or the performance of sewage disposal systems. Nor will it impact the water supply wells in the vicinity.

6. Coordination with appropriate Federal, State, and local agencies insured that concerns and suggestions were made known to the Corps so that these items could be addressed during project

planning.

Based on my review and evaluation of the environmental effects as presented in the EA, I have determined that the proposed Section 1135, Environmental Restoration Project at the Sagamore Marsh in Sandwich and Bourne, Massachusetts is not a major Federal action significantly affecting the quality of the human environment. This project is therefore, exempt from requirements to prepare an Environmental Impact Statement.

28 June 96 | William T. Scully | Deputy Division Engineer for Project Management

Date

for Earle C. Richardson
Colonel, Corps of Engineers
Division Engineer

NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS, WALTHAM, MA
CLEAN WATER ACT
SECTION 404(b)(1) EVALUATION

PROJECT: Sagamore Marsh Environmental Restoration Project

PROJECT MANAGER: Matthew Walsh TEL. (617) 647-8647

FORM COMPLETED BY: Larry Oliver TEL. (617) 647-8347

PROJECT DESCRIPTION:

The recommended alternative for this project is described in detail in Section 9 of the feasibility report. In general, the proposed plan involves the installation of culverts through Scusset Beach Road and the Canal service road, or bike path, and increasing the size of the existing outlet channel.

The new culverts will consist of 6-feet high by 12-feet wide culverts under each outlet crossing. The set of culverts beneath the bike path will be equipped with sluice gates and a backup flow control system to control the level of tidal water during storms.

The existing 1,300 foot riprap channel will be deepened and widened to improve hydraulic conveyance capacity. The bottom width will be increased from approximately 4 ft to 12 ft by excavating and moving the east bank of the channel 8 ft toward the east and replacing the 2:1 side slope. Stone protection will be replaced up to elevation 5 ft NGVD on the east bank. The remainder of this bank up to existing grade will be topsoiled and hydroseeded with an erosion control mixture containing switchgrass (*Panicum virgatum*).

Two upland staging areas will be established. One will abut the east side of the downstream channel segment and the south side of Scusset Beach Road. The second will be located on the west side of the riprap channel above Scusset Beach Road. A thirty-foot wide work area will be cleared of vegetation along the west side of the riprap channel bank above Scusset Beach Road and along the east side of the channel between the bike path and Scusset Beach Road.

Construction will take place during the 9-month period between August 1 and May 1 with the culvert and channel work occurring after October 1. A temporary road will be constructed across the channel to allow continued access to areas east of the construction area. To maintain tidal flow and freshwater outflow during the construction period, a temporary 48-inch corrugated metal pipe (CMP) will be placed in the channel under the temporary road between the two existing culverts. Flow will be conducted around each of the existing culverts during excavation and replacement by installing metal sheeting. The channel will be constructed in segments to minimize exposure of disturbed earth to tidal flow. Segments will be excavated, then stabilized with riprap before following segments are excavated.

The following general sequence will be followed: 1) Install erosion controls and clear staging areas; 2) construct upstream channel segment; 3) install bypass CMP and raodway; 4) install bike path culvert and gates; 5) install Scusset Beach Road culvert; 6) construct downstream channel segment.

The stone from the existing riprap will be reused on-site. Excavated material that can not be reused for construction will be disposed of at the Bourne town landfill or in a suitable offsite upland location.

Mosquito control will be implemented as needed by the local sponsor to ensure that the restoration of tidal flow does not increase mosquito populations.

Monitoring of vegetation, including salt marsh and eelgrass, and vegetation/hydrology relationship is required. Monitoring is described in 5.f. of this document and Appendix G of the main report.

NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS, WALTHAM, MA

<u>PROJECT:</u> Sagamore Marsh Restoration Project, Sandwich and Bourne, Massachusetts

Evaluation of Clean Water Act, Section 404(b)(1) Guidelines

1. <u>Review of Compliance (Section 230.10(a)-(d)).</u>
   a. The discharge represents the least environmentally damaging practicable alternative and if in a special aquatic site, the activity associated with the discharge must have direct access or proximity to, or be located in the aquatic ecosystem to fulfill its basic purpose. (If no, see section 2 and information gathered for EA alternative.)

   X YES ___ NO

   b. The activity does not appear to: 1) violate applicable state water quality standards or effluent standards prohibited under Section 307 of the CWA; 2) jeopardize the existence of Federally listed threatened and endangered species or their habitat; or 3) violate requirements of any Federally designated marine sanctuary.

   X YES ___ NO

   c. The activity will not cause or contribute to significant degradation of waters of the U.S. including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values.

   X YES ___ NO

   d. Appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic environment.

   X YES ___ NO

2. Technical Evaluation Factors (Subparts C-F).

a. Potential Impacts on Physical and Chemical Characteristics of the Aquatic Ecosystem (Subpart C).

	N/A	Not Significant	Significant
1) Substrate.		X	
2) Suspended particulates/turbidity.		X	
3) Water column impacts.		X	
4) Current patterns and water circulation.		X	
5) Normal water fluctuations.		X	
6) Salinity gradients.		X	

b. Potential Impacts on Biological Characteristics of the Aquatic Ecosystem (Subpart D).

	N/A	Not Significant	Significant
1) Threatened and endangered species.	X		
2) Fish, crustaceans, mollusks, and other organisms in the aquatic food web.		X	
3) Other wildlife (mammals, birds, reptiles and amphibians).		X	

c. Potential Impacts on Special Aquatic Sites (Subpart E).

	N/A	Not Significant	Significant
1) Sanctuaries and refuges.		X	
2) Wetlands.		X	
3) Mud flats.		X	
4) Vegetated shallows.		X	
5) Coral reefs.	X		
6) Riffle and pool complexes.	X		

d. Potential Effects on Human Use Characteristics (Subpart F).

	N/A	Not Significant	Significant
1) Municipal and private water supplies.		X	
2) Recreational and commercial fisheries.		X	
3) Water-related recreation.		X	
4) Aesthetic impacts.		X	
5) Parks, national and historic monuments, national seashores, wilderness areas, research sites and similar preserves.		X	

3. Evaluation and Testing (Subpart G).

a. The following information has been considered in evaluating the biological availability of possible contaminants in dredged or fill material. (Check only those appropriate.)

1) Physical characteristics........................... X
2) Hydrography in relation to known or anticipated sources of contaminants........................... X
3) Results from previous testing of the material or similar material in the vicinity of the project........................... ___
4) Known, significant sources of persistent pesticides from land runoff or percolation........................... ___
5) Spill records for petroleum products or designated hazardous substances (Section 311 of CWA)........................... ___
6) Public records of significant introduction of contaminants from industries, municipalities, or other sources..... ___
7) Known existence of substantial material deposits of substances which could be released in harmful quantities to the aquatic environment by man-induced discharge activities.............. ___
8) Other sources (specify)........................... ___

List appropriate references. See Environmental Assessment.

b. An evaluation of the appropriate information in 3a above indicates that there is reason to believe the proposed dredge or fill material is not a carrier of contaminants, or that levels of contaminants are substantively similar at extraction and disposal sites and not likely to require constraints. The material meets the testing exclusion criteria.

X YES ___ NO

4. Disposal Site Delineation (Section 230.11(f)).

a. The following factors, as appropriate, have been considered in evaluating the disposal site.

1) Depth of water at disposal site.................. X
2) Current velocity, direction, and variability at disposal site..................... X
3) Degree of turbulence............................ ___
4) Water column stratification..................... ___
5) Discharge vessel speed and direction....................................... ___
6) Rate of discharge............................... ___
7) Dredged material characteristics (constituents, amount, and type of material, settling velocities)................ X
8) Number of discharges per unit of time.. ___
9) Other factors affecting rates and patterns of mixing (specify).................... ___

List appropriate references. See Environmental Assessment.

b. An evaluation of the appropriate factors in 4a above indicated that the disposal sites and/or size of mixing zone are acceptable.

X YES ___ NO

5. Actions To Minimize Adverse Effects (Subpart H).

All appropriate and practicable steps have been taken, through application of recommendation of Section 230.70-230.77 to ensure minimal adverse effects of the proposed discharge.

X YES ___ NO

List actions taken.

The following actions will be taken to minimize adverse impacts to the biological resources within the project area:

a. Construction will be segmented to minimize water quality impacts (i.e. turbidity) to the maximum extent practicable.

b. Temporary access roads will be removed following construction and any disturbed areas that threaten to create turbidity problems will be restored.

d. All reasonable precautions will be taken by equipment operators when working in wetlands and intertidal areas to avoid impacting vegetation and benthic organisms.

e. Appropriate sedimentation controls will be employed to minimize off-site impacts.

f. The following monitoring will be performed to ensure adverse impacts to wetlands and vegetated shallows are avoided:

Wetlands: salt marsh. To ensure successful salt marsh restoration, appropriate levels of surface flooding and soil drainage must occur.

Salt marsh plants require surface flooding and soil drainage within certain limits. The marsh surface and soil near the creekbanks should be flooded and drained by tides. Further from the creeks, the marsh surface should be flooded and drained during each flooding tidal cycle. To establish salt marsh vegetation, the marsh should be flooded between eight times monthly and once daily.

Establish approximately ten permanent sample stations at two marsh transects (Transect 1 and a new transect between Transects 2 and 4). Record the marsh surface elevation, depth of soil water during low tide, depth of flooding relative to surface elevation at high and low water during spring and neap tide phases, plant species composition, percent cover, height and density of common reed (Phragmites australis), and height of salt marsh cordgrass (Spartina alterniflora). Sampling will be conducted prior to project implementation, immediately following implementation, and during August of each of the five years following implementation.

Vegetated shallows: eelgrass. The main channel in the Sagamore Marsh currently supports dense eelgrass (Zostera marina). To ensure the continued vigor of the eelgrass, permanent flooding of the channel bottom (subtidal habitat) is recommended. While eelgrass grows intertidally, it is desirable and may be essential to maintain some permanent water (at least one foot) in the main channel at least over the area where eelgrass presently occurs.

Establish three permanent plots. Measure percent cover, height, and density of eelgrass plants during August of each year. Sampling will be conducted prior to construction and for a period of three to five years depending on sampling results.

6. Factual Determination (Section 230.11).

A review of appropriate information, as identified in items 2 - 5 above, indicates there is minimal potential for short or long term net negative environmental effects of the proposed discharge as related to:

a. Physical substrate at the disposal site (review sections 2a, 3,4, and 5 above). YES _X_ NO __

b. Water circulation, fluctuation and salinity (review sections 2a, 3, 4, and 5). YES _X_ NO __

c. Suspended particulates/turbidity (review sections 2a, 3, 4, and 5). YES _X_ NO __

d. Contaminant availability (review sections 2a, 3, and 4). YES _X_ NO __

e. Aquatic ecosystem structure, function, and organisms (review sections 2b and c, 3, and 5). YES _X_ NO __

f. Proposed disposal site (review sections 2, 4, and 5). YES _X_ NO __

g. Cumulative effects on the aquatic ecosystem. YES _X_ NO __

h. Secondary effects on the aquatic ecosystem. YES _X_ NO __

7. Findings of Compliance or Non compliance

The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines.
......................................YES _X_ NO __

28 June 96
DATE

William [signature] Deputy Division Engineer for Project Management
for Earle C. Richardson
Colonel, Corps of Engineers
Division Engineer

APPENDIX EA-A
PERTINENT CORRESPONDENCE

L. Oliver

January 5, 1996

Planning Directorate
Evaluation Division

Ms. Hanni Dinkeloo
Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries and Wildlife
Route 135
Westborough, Massachusetts 01581

Dear Ms. Dinkeloo:

The Natural Heritage and Endangered Species Program has indicated that four-toed salamanders, a State Species of Concern, are present at the Sagamore Marsh Restoration Project site. As follow-up to your discussion with Mr. Larry Oliver of my staff, I am providing you additional information to complete your review of the project. The maximum level of salt water in the marsh will be less than elevation 4 feet NGVD (Enclosure 1). The direct construction impacts of the project will be located within and adjacent to the existing straight riprap channel at the entrance to the marsh. A draft culvert plan is enclosed (Enclosure 2).

We request your determination as to the significance of any potential project impacts on this species. It is very important that we resolve this issue before closing the feasibility phase of our investigation. Please contact Mr. Oliver at (617) 647-8347 if you have any questions about this information or the project.

Sincerely,

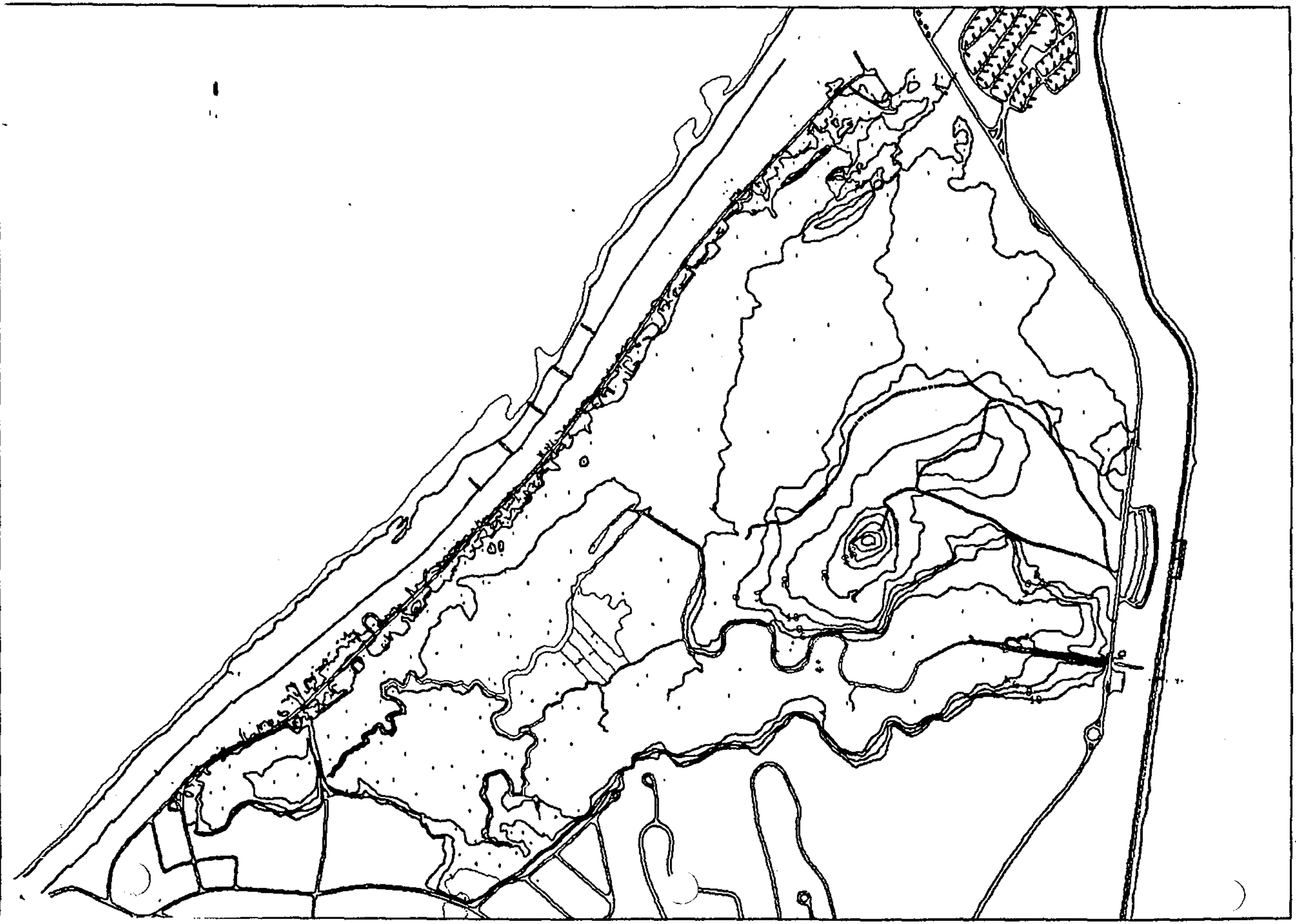
Joseph L. Ignazio
Director of Planning

Attachments

Copy furnished:
Ms. Christy Foote-Smith
Massachusetts Executive Office of Environmental Affairs
Wetlands Restoration and Banking Program
100 Cambridge Street
Boston, Massachusetts 02202

cc: Oliver
Hubbard (CC Mail)
Walsh
Read File
Plng. Ofc. File
Eval. Div. File

ENCLOSURE 1



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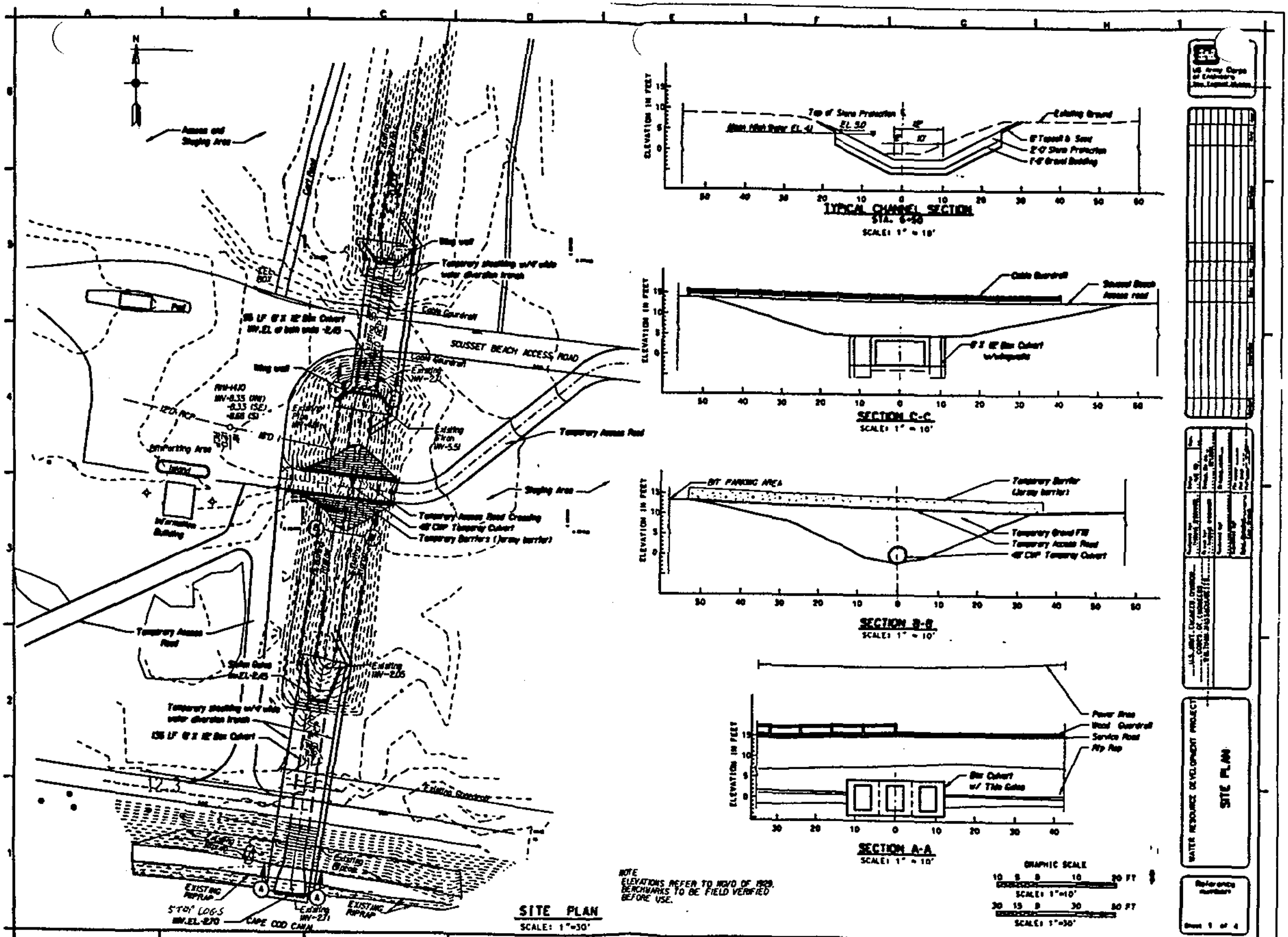

TYPICAL CHANNEL SECTION
SCALE: 1" = 10'
ELEVATION IN FEET
Existing Ground
SECTION C-C
SCALE: 1" = 10'
Cable Guardrail
SECTION B-B
SCALE: 1" = 10'
B/T PARKING AREA
Temporary Barrier (Jersey barrier)
SECTION A-A
SCALE: 1" = 10'
Power Area
Wood Guardrail
Service Road
Rip Rap
SCOUSSET BEACH ACCESS ROAD
Temporary Access Road
Staging Area
Information Building
Wing wall
Cable Guardrail
EXISTING RIPRAP
CAPE COD CANAL
NOTE
ELEVATIONS REFER TO NGVD OF 1929. BENCHMARKS TO BE FIELD VERIFIED BEFORE USE.
SITE PLAN
SCALE: 1"=30'
GRAPHIC SCALE
SCALE: 1"=10'
SCALE: 1"=30'
US Army Corps of Engineers
WATER RESOURCE DEVELOPMENT PROJECT
SITE PLAN

ENCLOSURE 2

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Wayne F. MacCallum, *Director*

December 6, 1995

Joseph L. Ignazio, Director of Planning
Planning Directorate, Impact Analysis Division
Army Corps of Engineers, New England Division
424 Trapelo Road
Waltham, MA 02254

Dear Mr. Ignazio:

In response to your request to Wayne MacCallum, Director of Massachusetts Division of Fisheries & Wildlife, of September 21, 1995, for comments on the Sagamore Marsh Restoration Project, I am sending the following, which incorporates thoughts on the subject from a variety of staff in Mass DFW. Hanni Dinkeloo, Environmental Reviewer for DFW's Natural Heritage & Endangered Species Program, will be responding separately about the rare species on site.

The Division of Fisheries & Wildlife supports the restoration effort. Despite the fact that the existing Phragmites does provide some escape habitat and cover for some species of wildlife, the consensus was that remnant patches of Phragmites and native shrubs on the upland edges will provide habitat for those species and the expanded salt marsh will enhance habitat for other native species whose habitat is currently diminished by the Phragmites.

Sincerely yours,

Patricia Swain

Patricia Swain, PhD
Plant Community Ecologist

cc. Larry Oliver, ACOE
Wayne MacCallum, Director, DFW
Hanni Dinkeloo and Patricia Huckery, NHESP-DFW

Natural Heritage & Endangered Species Program
Route 135, Westborough, MA 01581 Tel: (508) 792-7270 x 200 Fax: (508) 792-7275
An Agency of the Department of Fisheries, Wildlife & Environmental Law Enforcement

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
One Blackburn Drive
Gloucester, MA 01930

October 26, 1995

Joseph L. Ignazio
Director of Planning
Evaluation Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Ignazio:

Thank you for your September 21, 1995, letter soliciting comments regarding the Section 1135 investigation at the Sagamore Marsh in Sandwich, Massachusetts. The study is considering alternative measures to restore between 35 and 90 acres of salt marsh and estuarine habitat which has been impacted since the construction of the Cape Cod Canal. Based on the information you provided, the National Marine Fisheries Service supports the proposed restoration project.

On October 12, 1995, we conducted a site visit to the Sagamore Marsh. During this visit we observed the modifications which resulted in decreased tidal flow between the Cape Cod Canal and Sagamore Marsh. Culvert pipes are visibly inadequate in size and orientation to allow for a proper flow to sustain what was originally over a one hundred acre salt marsh. Because of the culvert's small size (48") and position above the mean low water, tidal flow into the marsh actually drops down a few inches between the culvert and the marsh. This observation indicates that compared to the pre-construction conditions, the marsh is receiving an inadequate quantity of tidal flow.

A combination of reduced tidal flow and increased freshwater runoff from upland development, has significantly impacted the biological character and ecological value of this salt marsh system. The dominant marsh vegetation has changed from Spartina salt marsh grasses to Phragmites australis, a species indicative of disturbed fresh- and brackish-water marshes. This intrusive reed species covers practically the entire marsh and only a relatively small portion of Spartina remains in close proximity to the canal where tidal circulation is the greatest. There is also evidence of further degradation of the marsh with scattered upland trees and shrubs taking root on what was historically salt marsh.

This restoration effort presents an opportunity for retroactive mitigation of some of the impacts resulting from the construction of the Cape Cod Canal before many of the values of salt marsh habitat were recognized. This particular restoration project is preferable to an off-site wetlands creation project, especially since many of the essential physical and biological components of a healthy salt marsh are still present. Potential access to increased tidal circulation, the availability of seed stock for both salt marsh plant and animal species and acres of appropriate substrates should all contribute to the project's success.

As this project proceeds from the planning stage to implementation we offer the following recommendations for consideration:

1. Maintain the quality of the existing in-channel estuarine habitat as much as practicable.
The channel leading into the marsh provides habitat that currently supports healthy patches of blue mussels and eelgrass. This area represents some of the last vestiges of pre-Cape Cod Canal habitat within the marsh. Protecting this area should support the restoration of salt marsh species throughout the degraded portions of the marsh once tidal circulation is increased.

2. Implement a monitoring program which assesses the effectiveness of the restoration project.
Monitoring should be an important part of any restoration project. Monitoring should profile both biological and physical parameters for as long into the future as possible. The marsh has undergone over sixty years of impacts and this project offers a unique opportunity to document what will probably be a comparably lengthy recovery. We recommend a monitoring scheme which maps the change in vegetation, animals, and salinity gradients.

This project has received support from local, state and federal resource agencies, but there is also some opposition from local residents. Since this project will provide substantial benefits to the marine environment, we suggest that as part of the monitoring program, an outreach program be established to educate the public on the benefits of marsh restoration.

3. Evaluate the benefits and impacts associated with active eradication of the <u>Phragmites australis.</u>
Removal of competing vegetation can support the propagation of desired salt marsh plant and animal species. Therefore, the benefits of eradicating <u>Phragmites</u> early in the restoration process should be explored.

Thank you for the opportunity to supply the Corps with some preliminary comments while this project is still in the developmental stage. We will provide more specific comments once a preferred alternative is identified and some of the impacts are described. If you have any questions, please contact Eric W.

Hutchins at 508-281-9313.

Sincerely,

Chris Mantzaris,
Chief, Habitat and Protected
Resources Division

cc: Phil Morrison - USFWS, Concord
Ed Reiner - USEPA, Boston
Deerin Babb-Brott - MACZM, Boston

File: 1503-07 -MA- Sagamore Marsh

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New England Field Office
22 Bridge Street, Unit #1
Concord, New Hampshire 03301-4986

October 25, 1995

Mr. Joseph L. Ignazio
Director of Planning
New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

ATTN: Evaluation Division

Dear Mr. Ignazio:

This responds to your letter of September 21, 1995, relative to the Section 1135 study of the Sagamore Marsh in Sandwich, Massachusetts. These comments are submitted in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the Endangered Species Act.

The goal of the project is to restore saltmarsh and estuarine habitats by modifying an existing Corps of Engineers structure. Alternatives under investigation are expected to result in the restoration of between 35-90 acres of wetlands, depending on the size of culvert installed. Other elements of the project include reconstruction of the existing riprap channel to convey tidal flow into the marsh, and installation of either self-regulating or manually operated tide gates to prevent upland flooding.

The Fish and Wildlife Service is pleased to support this project as part of the Coastal America partnership. Along with the Service's Partners For Wildlife program and the Massachusetts Wetlands Restoration Program, many acres of wetlands and other habitats have already been restored in Massachusetts. The Sagamore Marsh project will add to this total, and restore the habitat of waterfowl, wading and shore birds, and other wildlife. We will be happy to continue working with you to implement this project.

Based on information currently available to us, no federally-listed or proposed, threatened and endangered species under the jurisdiction of the U.S. Fish and Wildlife Service are known to occur in the project area, with the exception of occasional, transient bald eagles (*Haliaeetus leucocephalus*) or peregrine falcons (*Falco peregrinus*). However, we suggest that you contact Hanni Dinkeloo of the Massachusetts Natural Heritage and Endangered Species Program, Division of Fisheries and Wildlife, 1 Rabbit Hill Road, Westborough, MA 01581-3337, at 508-792-7270, for information on state-listed species that may be present.

Preparation of a Biological Assessment or further consultation with us under Section 7 of the Endangered Species Act is not required. Should project plans change, or additional information on listed or proposed species becomes available, this determination may be reconsidered.

Please continue to coordinate this project with Mr. Bob Scheirer of my staff. He can be reached at 603-225-1411.

Sincerely yours,

Michael J. Bartlett
Supervisor
New England Field Office

September 21, 1995

Planning Directorate
Evaluation Division

Ms. Patricia Swain
Natural Heritage and Endangered Species Program
One Rabbit Hill Road
Westboro, Massachusetts 01581

Dear Ms. Swain:

Thank you for your response to our request concerning effects of the Sagamore Marsh Restoration Project on wildlife. The purpose of this letter is to formally request a state list of endangered or threatened species for the project area.

To briefly summarize the project again, the Section 1135 study is investigating alternatives expected to result in the restoration of about 35 to 90 acres of salt marsh and estuarine habitat, now dominated by common reed and shrub vegetation. There are three major elements to the project alternatives:

1. Installation of new, larger-sized culverts through the Cape Cod Canal embankment and Scusset Beach Road replacing the existing culverts at the southern end of the marsh. Culvert sizes under investigation range from a single 6-foot by 6-foot culvert to twin 10-foot by 20-foot culverts.

2. Reconstruction of the existing riprap channel to convey tidal water into and out of the marsh system.

3. Construction/installation of self-regulating and/or manually operated tide gates to prevent upland flooding.

If you require any further information about the project or the affected area, please contact Mr. Larry Oliver of the Impact Analysis Division at (617) 647-8347.

Sincerely,

Joseph L. Ignazio
Director of Planning

Enclosure
cc: Mr. Oliver
Mr. Walsh - 114N
Mr. Hubbard
Read File
Plng. Ofc. File, Eval Div Files

September 21, 1995

Planning Directorate
Evaluation Division

Mr. Chris Mantzaris, Supervisor
National Marine Fisheries Service
1 Blackburn Drive
Gloucester, Massachusetts 01930-3097

Dear Mr. Mantzaris:

We are conducting a Section 1135 investigation at the Sagamore Marsh in Sandwich, Massachusetts to consider alternatives for modifying the Corps of Engineers structures to restore fish and wildlife resources. We have been coordinating this effort with Mr. John Catena of your staff. The purpose of this letter is to formally request your comments on the project pursuant to the Fish and Wildlife Coordination Act. Please find enclosed a location map of the area to aid you in your work.

The goal of the project is to restore the previously existing salt marsh and estuarine habitats. There are three major elements to the project alternatives:

1. Installation of new, larger-sized culverts through the Cape Cod Canal embankment and Scusset Beach Road replacing the existing culverts at the southern end of the marsh.

2. Reconstruction of the existing riprap channel to convey tidal water into and out of the marsh system.

3. Construction/installation of self-regulating and/or manually operated tide gates to prevent upland flooding.

The Section 1135 study is investigating alternatives expected to result in the restoration of about 35 to 90 acres of salt marsh and estuarine habitat, now dominated by common reed and shrub vegetation. Culvert sizes under investigation range from a single 6-foot by 6-foot culvert to twin 10-foot by 20-foot culverts.

If you require any further information about the project or the affected area, please contact Mr. Larry Oliver of the Impact Analysis Division at (617) 647-8347.

Sincerely,

Joseph L. Ignazio
Director of Planning

Enclosure

cc: Mr. Oliver
Mr. Walsh - 114N
Mr. Hubbard
Read File
Plng. Ofc. File
Eval Div Files

September 21, 1995

Planning Directorate
Evaluation Division

Mr. Michael Bartlett, Supervisor
Fish and Wildlife Service
Ecological Services
400 Ralph Pill Building
22 Bridge Street
Concord, New Hampshire 03301-4901

Dear Mr. Bartlett:

We are conducting a Section 1135 investigation at the Sagamore Marsh in Sandwich, Massachusetts to consider alternatives for modifying the Corps of Engineers structures to restore fish and wildlife resources. We have been coordinating this effort with Mr. Scheirer of your staff. The purpose of this letter is to formally request your comments on the project pursuant to the Fish and Wildlife Coordiination Act and a list of endangered or threatened species for the project area, pursuant to Section 7(c) of the Endangered Species Act of 1973, as amended. Please find enclosed a location map of the area to aid you in your work.

The goal of the project is to restore the previously existing salt marsh and estuarine habitats. There are three major elements to the project alternatives:

1. Installation of new, larger-sized culverts through the Cape Cod Canal embankment and Scusset Beach Road replacing the existing culverts at the southern end of the marsh.

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If you require any further information about the project or the affected area, please contact Mr. Larry Oliver of the Impact Analysis Division at (617) 647-8347.

Sincerely,

Joseph L. Ignazio
Director of Planning

Enclosure

cc: Mr. Oliver
Mr. Walsh - 114N
Mr. Hubbard
Read FIle
Plng. Ofc. File
Eval Div Files

September 21, 1995

Planning Directorate
Evaluation Division

Mr. Wayne MacCallum
Massachusetts Division of Fisheries and Wildlife
100 Cambridge Street
Boston, Massachusetts 02202

Dear Mr. MacCallum:

We are conducting a Section 1135 investigation at the Sagamore Marsh in Sandwich, Massachusetts to consider alternatives for modifying Corps of Engineers structures to restore fish and wildlife resources. We have been coordinating this effort with Ms. Patricia Swain of your staff and would like to thank you for her input. The purpose of this letter is to formally request your comments on the project pursuant to the Fish and Wildlife Coordination Act. Please find enclosed a location map of the area to aid you in your work.

The goal of the project is to restore the previously existing salt marsh and estuarine habitats. There are three major elements to the project alternatives:

1. Installation of new, larger-sized culverts through the Cape Cod Canal embankment and Scusset Beach Road replacing the existing culverts at the southern end of the marsh.

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If you require any further information about the project or the affected area, please contact Mr. Larry Oliver of the Impact Analysis Division at (617) 647-8347.

Sincerely,

Joseph L. Ignazio
Director of Planning

Enclosure

cc: Mr. Oliver
Mr. Walsh - 114N
Mr. Hubbard
Read File
Plng. Ofc. File
Eval Div Files

September 21, 1995

Planning Directorate
Evaluation Division

Mr. Douglas Beach
National Marine Fisheries Service
Habitat Conservation Office
1 Blackburn Drive
Gloucester, Massachusetts 01930-3097

Dear Mr. Beach:

We are conducting a Section 1135 investigation at the Sagamore Marsh in Sandwich, Massachusetts to consider alternatives for modifying Corps of Engineers structures to restore fish and wildlife resources. The purpose of this letter is to request a list of endangered or threatened species for the project area, pursuant to Section 7(c) of the Endangered Species Act of 1973, as amended. Please find enclosed a location map of the area to aid you in your work.

The goal of the project is to restore the previously existing salt marsh and estuarine habitats. There are three major elements to the project alternatives:

1. Installation of new, larger-sized culverts through the Cape Cod Canal embankment and Scusset Beach Road replacing the existing culverts at the southern end of the marsh.

2. Reconstruction of the existing riprap channel to convey tidal water into and out of the marsh system.

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The Section 1135 study is investigating alternatives expected to result in the restoration of about 35 to 90 acres of salt marsh and estuarine habitat, now dominated by common reed and shrub vegetation. Culvert sizes under investigation range from a single 6-foot by 6-foot culvert to twin 10-foot by 20-foot culverts.

If you require any further information about the project or the affected area, please contact Mr. Larry Oliver of the Impact Analysis Division at (617) 647-8347.

Sincerely,

Joseph L. Ignazio
Director of Planning

Enclosure

cc: Mr. Oliver
Mr. Walsh - 114N
Mr. Hubbard
Read File
Plng. Ofc. File
Eval Div Files

CENEDPL-I (1105-2-10) 18 October 1994

MEMORANDUM FOR THE RECORD Rec'd dlty 10-21-94

SUBJECT: Sagamore Marsh Restoration - Coordinated Site Visit

1. **Date of Meeting:** 13 September 1994

2. **Location:** Scusset Beach Parking Lot and Project Site

3. **Principal Participants:** See attached

4. **Report:** This purpose of this meeting was to provide environmental agencies with an early opportunity to view the project site and comment on the project and evaluation process. The meeting was well attended; Christy Foote-Smith of the Massachusetts Wetlands Restoration and Banking program sent a memo to state agencies encouraging them to attend.

Matt Walsh, the study manager, presented a description of the project and I described our evaluation process, environmental resources, and the site investigations to date. We viewed the location of the existing culvert through the Cape Cod Canal embankment, the channels, and the marsh from Sagamore Hill.

The following comments were made during the site meeting:

Dave Shepardson of MEPA suggested that we have a control system such as stop logs to make minor project adjustments. He indicated that the EIR could be coordinated with the EA.

Gene Kavanaugh DEM suggested that we match up the State and Federal processes as soon as possible. He suggested that we make the design as simple as possible so maintenance would be easier. Someone else from DEM was concerned about how the local sponsor (probably DEM) would handle O&M on our property.

Paul Carusso of the Division of Marine Fisheries indicated that the Division would be most concerned with water quality effects and the construction sequencing to minimize impacts. Someone asked about anadromous fish and Mr. Carusso indicated that only white perch are likely to use the creek.

Someone was concerned about the effect of the project on mosquitoes. I indicated that, depending on the future habitat type open marsh water management may have to be implemented by the local sponsor.

Bill Remes of DEM indicated that we should consider whether the project will affect the trailer waste pumpout station; it may need to be moved.

Steve Ivas suggested that we determine if the wetland has been mapped under the Wetlands Restriction program and is subject to restrictions.

5. **Importance to NED:** This meeting allowed environmental agencies to view the site and express opinions about the project at an early phase. No significant concerns were identified.

Larry Oliver

LARRY OLIVER

cc: Hubbard
Walsh-114N
IAD Files

SAGAMORE MARSH
ENVIRONMENTAL SITE VISIT

9/13/94

NAME	REPRESENTING	TEL #
LARRY OLIVER	CORPS OF ENGINEERS	617-647-8347
Paul Caruso	MDMF	508-888-1155
DANIEL F. GILMORE	DEP. DWW SERO	508.946.2808
Paul Innis	Bourne Public Schools	508 888 0150
Harold Stephens	DEP/DWS/Boston	617/292-5657
LARRY DAYIAN	DEP/DWS/LAKEVILLE	508-946-2769
Christy Foote-Smith	EOEA/WRBP	617-727-9800 x213
Steve Ivas	MDC/engineering	617.727.5264 x629
Judy Sheehy	Bourne Schools	508 888-6094
David Shepardson	EOEA/MEPA	617-727-5830 x304
Diane Bryant	Bourne Con Com	508-759-0625
KAREN SHERMAN	BOURNE TOWN PLANNER	(508) 759-0616
Richard Curafoi	Scusset Beach	(508) 888-0859
Eugene F. Cavanaugh	DEM/Waterways	617-740 1600
BILL ROMES	DEM	
Pam RUBINOFF	CZM	508.362.3828
MARK GALKOWSKI	Sandwich Con Com	
BOURKE	Sandwich Asst. Town Admin.	

ADDED TO LIST / ATTENDEES

L. Oliver

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02254-9149

REPLY TO
ATTENTION OF

August 23, 1994

Planning Directorate
Impact Analysis Division

Mr. John Simpson
Department of Environmental Protection
Division of Waterways Regulation
20 Riverside Drive
Lakeville, Massachusetts 02347

Dear Mr. Simpson:

The U.S. Army Corps of Engineers is conducting a Section 1135, environmental restoration study, at Sagamore Marsh in Sandwich, Massachusetts (see attached map). The study area includes approximately 250 acres of former salt marsh and estuarine habitat. We are studying the possibility of restoring tidal flow to the existing common reed marsh to restore salt marsh and estuarine habitat.

A site visit for environmental organizations is scheduled for Tuesday, September 13, 1994 at 11:00 a.m. at the Scusset Beach parking lot near the state fishing pier. A brief description of the project will be presented. This meeting will provide an early opportunity for comment and exchange of information on the project.

Please contact Mr. Larry Oliver of my staff at (617) 647-8347, if you will be sending a representative to the site visit or if you have any questions about this project.

Sincerely,

Joseph L. Ignazio
Director of Planning

Attachment

SAME LETTER SENT TO:

Mr. Philip G. Coates, Director
MA Division of Marine Fisheries
100 Cambridge Street
Boston, Massachusetts 02202

Mr. John Higgins, Director
Dept. of Environmental Protection
Division of Water Pollution Control
One Winter Street
Boston, Massachusetts 02108

Mr. Scott Hecker
Massachusetts Audubon Society
South Great Road
Lincoln, Massachusetts 01773

Mr. Carl Dierker
Mass. Dept. of Environmental Protection
Division of Wetlands/Waterways
One Winter Street
Boston, Massachusetts 02108

Mr. Eugene Cavanaugh, Director
Mass. Bureau of Coastal Engineering
100 Cambridge Street
Boston, Massachusetts 02202

Mr. Douglas Thompson
Chief, Wetlands Protection Section
U.S. Environmental Protection Agency
JFK Federal Building
Boston, Massachusetts 02203

Ms. Pamela Rubinoff
Mass. Coastal Zone Management
3225 Main Street, Box 226
Barnstable, Massachusetts 02630

Mr. Stephen Carpenter, Director
Department of Environmental Management
Division of Forests and Parks
100 Cambridge Street, Room 1905
Boston, Massachusetts 02202

Mr. Chris Mantzaris
National Marine Fisheries Service
1 Blackburn Drive
Gloucester, Massachusetts 01930

Mr. Gordon Beckett, Supervisor
U.S. Fish and Wildlife Service
400 Ralph Pill Building
22 Bridge Street
Concord, New Hampshire 03301

Mr. John Reitsma
MEPA Unit
100 Cambridge Street, 20th Floor
Boston, Massachusetts 02202

Mr. Thames Powers, Acting Commissioner
Mass. Dept. of Environmental Protection
One Winter Street
Boston, Massachusetts 02108

Mr. Wayne F. MacCallum, Director
Division of Fisheries and Wildlife
100 Cambridge Street, Room 1901
Boston, Massachusetts 02202

Mr. Charles Millen
Department of Natural Resources
1189 Phinney's Lane
Centerville, Massachusetts 02632

Mr. Mark Galkowski
Sandwich Conservation Commission
270 Quaker Meeting House Rd.
Sandwich, Massachusetts 02537

Ms. Diane Bryant
Bourne Conservation Commission
24 Perry Ave.
Bourne, Massachusetts

Copy furnished:
Ms. Christy Foote-Smith
Massachusetts Executive Office of
Environmental Affairs
Wetlands Restoration and Banking Program
100 Cambridge Street
Boston, MA 02202

Mr. Larry Dayain
Department of Environmental Protection
Division of Water Supply
20 Riverside Drive
Lakeville, Massachusetts 02347

Ms. Elizabeth Kouloheras
Department of Environmental Protection
Division of Wetlands and Waterways
20 Riverside Drive
Lakeville, Massachusetts 02347

Mr. John Simpson
Department of Environmental Protection
Division of Waterways Regulation
20 Riverside Drive
Lakeville, Massachusetts 02347

Mr. Bill Remes
Department of Environmental Management
Division of Forests and Parks
P O Box 66
S. Carver, Massachusetts 02366

APPENDIX EA-B
RESULTS OF BENTHIC SAMPLING

Benthic invertebrates from marsh restoration area, Sagamore, Massachusetts.

Sheldon D. Pratt
13 Sherman Court
Wakefield, RI 02879

Background

A salt marsh in Sagamore Beach, MA was modified during construction of the Cape Cod Canal when the southern end was filled. The natural meandering channel was straightened within the marsh, and continues as a straight channel about 300 meters long through fill, and enters the Canal through a culvert.

NED, COE personnel obtained 6 benthic samples along the channel from near the outlet culvert to the present southern end of the marsh. Samples were taken on sand within the channel center (1,2,3), within *Spartina alterniflora* marsh grass fringing the channel (4,5), and on marsh peat at the northern end of the channel (A). The samples were taken with a core tube with an area of 40.7 cm^2 sieved to 0.5 mm in the field and preserved in 10% formalin solution with Rose Bengal stain. Samples were delivered to the University of Rhode Island Graduate School of Oceanography for identification and enumeration of benthic infauna.

Methods

Samples were washed through a series of sieves to remove preservative, remaining fine sediment, and stain. In some samples plant detritus was separated from sand and shell by successive elutriation from a tall-form pitcher. Material retained on a 2 mm sieve was examined in water-filled trays without magnification. Fractions retained on 1mm and 0.5 mm sieves were examined under low powered microscopes.

Organisms were identified to species where possible. Small or damaged specimens which were similar to identified specimens were given that name rather than being reported as 'unidentified'. This procedure avoids confusion in comparing species diversity between studies. Marine oligochaetes are often not identified to species in environmental surveys since examination of internal organs under high magnification is required. In the Sagamore samples three species were identified by external characteristics, and the remaining individuals placed in to two categories which may include additional species.

Counts of organisms and a description of sample residue were entered on an Excel computer spreadsheet.Organisms were preserved in 70% alcohol and archived at the Graduate School of Oceanography.

Results

Organisms were well preserved and intact, but not well stained in samples with a large volume of marsh detritus or peat.

Counts of benthic organisms are given in Table 1. The relatively small area of the sampler was appropriate since a large number of individuals were recovered from each core. Polychaete and oligochaete annelids dominated all samples in both numbers of individuals and numbers of species. The small number of non-annelids present included one gastropod (*Hydrobia totteni*, { *H. minuta* in older literature }) and two bivalves (*Tellina agilis* and juvenile *Mya arenaria*). Arthropods present included small individuals of an isopod (*Edotea triloba*), two amphipod, and two insect species.

Because the sample stations are located close to each other in an area of high water exchange, there is little reason to expect an upstream-downstream gradient in water quality which would effect faunal composition. Although the sample number is low, it appears that three faunal assemblages are found in areas with different substrate and tidal exposure combinations.

Samples 1-3 in the channel center are characterized by relatively high diversity of species (13-17) and the presence of bivalve mollusks , the oligochaetes *Pelosolex benedeni* and several tubificids, and polychaetes in the families *Capitellidae* (*Capitella, Heteromastus, Mediomastus*), *Orbiniidae* (*Leitoscloplos*), *Nereidae* (*Neanthes succinea, N. virens*), and *Spionidae* (*Marenzelleria, Polydora, Streblospio*).

Samples 4 and 5 on intertidal sediment within stands of marsh grass had fewer species than the channel samples. although the high density of the oligochaete, *Lumbricillus* resulted in high total individuals. The most characteristic species in these stations were absent or nearly absent in the channel (*Manayunkia. Pygospio, Lumbricillus* and insect larvae). These species are adapted for exposure to variable salinity and temperature on the marsh surface. Most of the channel species were absent from these samples.

The sample on subtidal peat at station A included species in both the channel and marsh groups. Presumably this habitat is intermediate to those sites in terms of either tidal elevation , sediment grain size, or presence of marsh detritus.

The fauna in these samples is dominated by species which depend on organic particulate food, either on the sediment surface and in suspension. (the bivalve, T*ellina;* spionid and nereid polychaetes) or in subsurface sediments (oligochaetes; capitellid and orbiniid polychaetes). True suspension feeders such as *Mya* are not important in this system.

The average density of individuals found in samples 1,2,3, and A ($97,600/m^2$) is at the high end of reported values for estuarine assemblages. High densities of small polychaetes and oligochaetes may indicate pollution or other stress, however the density found is comparable to that reported in portions of marsh-dominated flats and creeks in Cape Cod with low levels of disturbance by man such as Barnstable Harbor (Whitlatch, 1977) and Great Sippewissett Marsh (Sarda et al, 1995), The species restricted to the sandy channel at Sagamore Marsh were mainly found on organic sand at Great Sippewissett. There appears to be some relation to the fauna in samples 4,5,and A and that found in inner muddy creeks at Great Sippewissett. A number of species present in other marsh systems were not found at Sagamore.These include species adapted for life on non-organic sand and for fully marine or brackish salinities. Additional sampling at the present location and within the marsh would increase the number of species found, including brackish water forms. It appears that species preferring clean sand and full salinity do not find appropriate habitat in the channel. The absence of mollusks with non-pelagic young like *Gemma gemma* and *Ilynassa obsoleta* from the channel, may be due to transport of adults out of the system with limited opportunity for entry

Many of the taxa found in the Sagamore Beach Marsh channel have been proposed as indicaters of pollution (*Capitella,Eteone, Neanthes succinea, Polydora cornuta , the family Spionidae, and the class Oligochaeta)* These species would have been present in the marsh before it was modified since they are adapted for variable salinity an abundance of particulate organic matter, and a reduced number of competitors and predators.

Acknowledgment : Sample sorting was carried out by M.E. Jackman.

References

Sarda, R.,K. Foreman, I. Valiela, 1995. Macroinfauna of a Southern New England salt marsh: Seasonal dynamics and production. Marine Biology 121:431-445.

Whitlatch, R.B. 1977. Seasonal changes in the community structure of the macrobenthos inhabiting the intertidal sand and mud flats of Barnstable Harbor, Massachusetts. Biol Bull mar biol lab, Woods Hole 152: 275-294.

TABLE 1. BENTHIC ORGANISMS RECOVERED FROM THE SOUTHERN PORTION OF THE SAGAMORE SALTMARSH, SAGAMORE/SANDWICH, MA [collected 10/26/94, core sample 40.7cm^2, sieved to 0.5mm, counts in parentheses not used in calculation of totals]						
	CHANNEL CENTER [SAND]			FRINGE MARSH		PEAT
SAMPLE NUMBER	1	2	3	4	5	A
CNIDARIA						
colonial hydroid fragment					[1]	
RHYNCHOCOELA						
Rhynchocoela sp E	1		1			1
Rhynchocoela sp. F						1
MOLLUSCA						
GASTROPODA						
Hydrobia totteni				1		30
BIVALVIA						
Mya arenaria juv.			2			
Tellina agilis	6	11				
ANNELIDA						
POLYCHAETA						
Capitella capitata	12	22	9			42
Eteone heterpoda	1	2				
Eumida sanguinea	1					
Heteromastus filiformis		1				
Leitoscloplos spp.		6	1			3
Manayunkia estuarina				1	5	3
Marenzelleria viridis	4	9	1			
Mediomastus ambiseta			9			
Neanthes succinea	17	9	5			
Neanthes virens	1		3			2
Polydora comuta	3	2	2			3
Pygospio elegans			1	14	2	51
Streblospio benedicti	61	167	139	1	1	133
Total Polychaeta	[100]	[218]	[170]	[16]	[8]	[237]
OLIGOCHAETA						
Lumbricillus lineatus				247	37	28
Peloscolex benedeni	11	31	29			63
Peloscolex sp.		5				
Tubificidae A	56	197	143	22		21
Tubificidae B	24	28	20			136
Total Oligochaeta	[91]	[261]	[192]	[269]	[37]	[248]
ARTHROPODA						
CRUSTACEA						
CIRRIPEDIA						
Balanus balanoides			[3]			

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	CHANNEL CENTER [SAND]			FRINGE MARSH		PEAT
SAMPLE NUMBER	1	2	3	4	5	A
ISOPODA						
Edotea triloba			2			6
AMPHIPODA						
Corophium sp.			4	1		
Amphipoda sp.			1			
INSECTA						
Ceratopogonid sp				2	1	
Tabanid sp.				1		
NUMBER OF ORGANISMS	198	490	372	290	46	523
NUMBR OF SPECIES	13	13	17	9	5	15
SIEVE RESIDUE						
VOLUME (cc)	25	135	70	90	200	1200
CONSTITUENTS	iron stained, worn fragments of shell,periostracum, marsh detritus Littorina, Geukensia shells wood frags.			marsh plant stems, rhizomes, fine detritus	marsh detritus	intact marsh peat, fine detritus